

Report 2

# Are GM crops better for the environment?

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**Collaborative Campaigning for Food Sovereignty and Environmental Justice**

The GMO Inquiry 2015 is a project of the Canadian Biotechnology Action Network (CBAN). CBAN is a campaign coalition of 17 organizations that researches, monitors and raises awareness about issues relating to genetic engineering in food and farming. CBAN members include farmer associations, environmental and social justice organizations, and regional coalitions of grassroots groups. CBAN is a project of Tides Canada Initiatives.

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**GM** = genetically modified (also called genetically engineered)    **Ht** = herbicide-tolerant  
**Gt** = glyphosate-tolerant    **GR** = glyphosate-resistant

# SUMMARY

In this second report of GMO Inquiry 2015, we investigate the environmental impacts of genetically modified (GM; also called genetically engineered or GE) crops in Canada, and around the world.

After 20 years, most of the GM crops grown in Canada are herbicide-tolerant, and the rest are insect-resistant (some are both). There is limited data in Canada to help us examine the relationship between GM crops and pesticide use but we can see that, in general, herbicide use has increased over the past 20 years. The widespread cultivation of glyphosate-tolerant crops, in particular, has driven up the use of glyphosate-based herbicides.

This increased use of glyphosate has resulted in the emergence and spread of glyphosate-resistant weeds. In response, biotechnology companies have genetically engineered crops to be tolerant to the older herbicides 2,4-D and dicamba. These GM crops will further increase the herbicide load in the environment and lead to even more herbicide-resistant weeds.

GM insect-resistant (Bt) crops have reduced insecticide use in some countries. The Canadian government has not monitored the impact of Bt crops on insecticide use in Canada. However, insects are beginning to develop resistance to Bt crops in the US and other countries, and farmers are turning to other insecticide applications to control them. Additionally, Bt plants themselves produce insecticidal toxins that are released into the environment.

GM crops have also had a number of impacts on biodiversity. Herbicide-tolerant crops reduce weed diversity in and around fields, which in turn reduces habitat and food for other important species, including the Monarch butterfly. Studies have also observed that Bt crops can have negative impacts on non-target insects, including pollinators, and soil and water organisms. In addition, gene flow from GM crops poses a threat to non-GM crops and wild and weedy crop relatives, particularly in global centres of origin and diversity. Such GM contamination threatens the future of organic and ecological farming in Canada.

Future risks from GM crops and animals may look quite different from our current reality, as new organisms with new GM traits are introduced into our environment and food systems. For example, Canada has just approved a GM “non-browning” apple, and GM herbicide-tolerant and low-lignin alfalfa could be sold in 2016 for the first time. The Minister of the Environment has approved the production of GM fast-growing salmon in Canada, though it is not yet approved for eating and is therefore not yet being grown. Canada also continues to allow field tests of GM forest trees. These GM crops and animals all pose new, unique risks that are hard to predict. Once they are released into the environment, however, genetically modified organisms are impossible to control or recall.

Overall, GM crops, trees and animals are rooted in, and perpetuate, a model of agriculture that has a number of serious environmental impacts and is not sustainable in the long-term.

# GMO INQUIRY 2015

**T**wenty years ago, in 1995, the Canadian government approved the first genetically modified (GM, also called genetically engineered or GE) canola varieties, as well as the first GM soy, GM tomatoes (not currently on the market) and GM potatoes (not currently on the market). With these decisions, the government introduced genetically modified crops into our environment and food system for the first time.

After 20 years, we still have major unanswered questions and hear conflicting messages about the impacts and risks of GM crops and foods. Even while our questions persist, the Canadian government has just approved the first-ever GM apple (this will be the first GM fruit grown in Canada) and could soon approve the first GM food animal (a GM salmon).

Canadian farmers and eaters want to know the impacts of GM crops – on our environment, our food and farming systems, our economy, and on our health. We want to know about the food we’re growing, eating and buying. And we want to know who truly benefits from GM crops and foods, and who pays their costs and bears the burden of their risks.

The Canadian government has not monitored or shared detailed information to answer these questions. However, research in Canada and from around the world, as well as the experiences of farmers in Canada and other countries, helps shed light on the problems with GM over the past two decades. It’s time to bring our research together and assess the evidence, so that we can decide whether GM crops have a place in the future of our food system.

This is the second in a series of reports that are part of the GMO Inquiry 2015. The reports are posted at [www.GMOinquiry.ca](http://www.GMOinquiry.ca) along with summary pamphlets.

The reports answer the following questions:

- Where in the world are GM crops and foods? [www.gmoenquiry.ca/where](http://www.gmoenquiry.ca/where)
- Are GM crops better for the environment? [www.gmoenquiry.ca/environment](http://www.gmoenquiry.ca/environment)
- Are GM foods better for consumers? [www.gmoenquiry.ca/consumers](http://www.gmoenquiry.ca/consumers)
- Are GM crops better for farmers? [www.gmoenquiry.ca/farmers](http://www.gmoenquiry.ca/farmers)
- Are GM crops and foods well regulated? [www.gmoenquiry.ca/regulation](http://www.gmoenquiry.ca/regulation)
- Do we need GM crops to feed the world? [www.gmoenquiry.ca/feedingtheworld](http://www.gmoenquiry.ca/feedingtheworld)



Read and print the summary pamphlet for this report at [GMOinquiry.ca/environment](http://GMOinquiry.ca/environment)

# ARE GM CROPS BETTER FOR THE ENVIRONMENT?

“ The agricultural choices we make as a society are of critical importance to our environment. Agriculture affects, and is in turn affected by our natural surroundings. Ecologically sound agriculture ensures the ongoing health of the ecosystem and depends upon a healthy ecosystem in order to function. In contrast, the fossil-fuel dependent industrial sectors of the food system treats inputs, (such as energy, fertilizers, pesticides, and water) as though they are of limitless supply and the environment as though it is limitless in its ability to absorb waste and pollution. We know that the foundations of the global food system, are, in fact, limited in supply and progressively compromised. — People’s Food Policy, Canada, 2011<sup>1</sup>

“ Monsanto’s research in crop and food improvements, using biotechnology methods, supports our commitment to the production of abundant food and a healthy environment for the world.

— “Abundant food and a healthy environment...”  
Monsanto, May 1995

“ It is now possible to breed crops with new characteristics, like resistance to insects, frost and disease, using genetic modification. And some of these new crops may reduce the need for chemicals in agriculture. — “Food Safety and You”, Government of Canada, householder (mailed to every household in Canada), 2001

**G**enetically modified crops have been a 20-year open-air experiment in Canada. What have we learned about the environmental impacts of genetically modified organisms (GMOs) over these 20 years? Are there environmental risks associated with continuing to use the GM crops that are being grown, and with introducing new GM crops and animals?

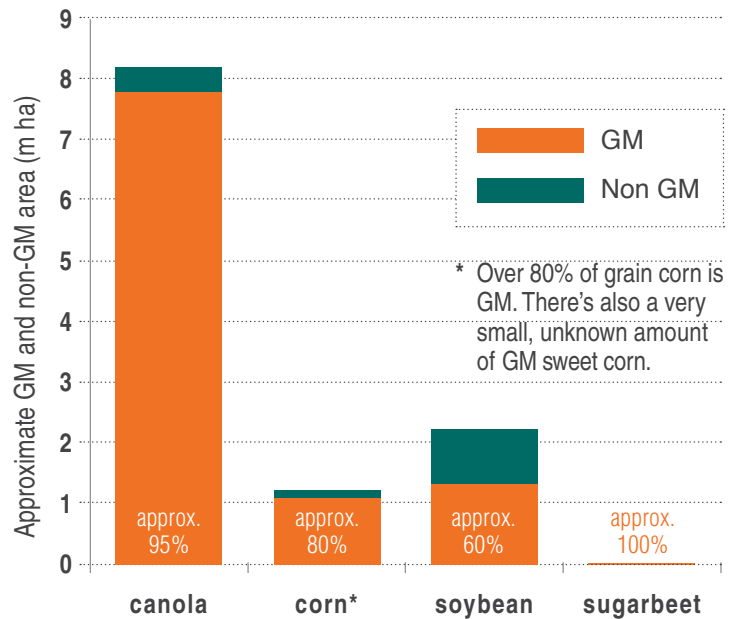
Four GM crops – soy, corn, canola and sugar beet – engineered to be herbicide-tolerant and/or insect-resistant, are grown in Canada.

These crop plants are living organisms; once they are released into the environment they cannot be controlled or recalled.

It is urgent that we understand the environmental impacts and risks of releasing GM organisms, in order to assess what role they should play in the future of food and farming. This evaluation is particularly important as we work to adapt our agricultural and food systems to a changing climate.

The world's largest biotechnology and seed company, Monsanto, calls itself a sustainable agriculture company, and has a new slogan: "Produce more. Conserve more. Improve Lives."<sup>2</sup> Monsanto says it is helping to reduce land use, soil loss, use of irrigated water, energy use and greenhouse gas emissions. But is this true? If so, how much of this is due to the application of GM technology?

**Figure 1: GM crops grown in Canada**



\* Over 80% of grain corn is GM. There's also a very small, unknown amount of GM sweet corn.

For details see "Where in the world are GM crops and foods?" [GMOinquiry.ca/where](http://GMOinquiry.ca/where)

## What is genetic modification?

Genetic modification (GM) is the introduction of new traits to an organism by making changes directly to its genetic makeup, e.g. DNA, through intervention at the molecular level. It's also called genetic engineering or GE. With genetic engineering, scientists can change the traits of plants and animals by inserting DNA pieces, whole genes, or long stretches of DNA segments from many different organisms. These sequences can also be taken from the same species or be newly made up. Scientists can also delete or swap DNA sequences in organisms or introduce genetic material to silence genes.

Unlike conventional breeding and hybridization, genetic engineering is a laboratory technology that enables the direct transfer of genes between organisms in different species or kingdoms that would not breed in nature, and the introduction of new sequences that do not even exist in nature.

# GM CROPS AND PESTICIDE USE

## HERBICIDE-TOLERANT CROPS AND HERBICIDE USE

The term “pesticides” includes herbicides, insecticides and fungicides.

Herbicide-tolerant (Ht) crops are genetically engineered to tolerate applications of a particular herbicide. This means that when farmers use specific herbicides on their Ht crops, the weeds are killed but the genetically modified herbicide-tolerant crops survive. Ht seeds are therefore used in partnership with particular herbicides, and have encouraged the use of those products.

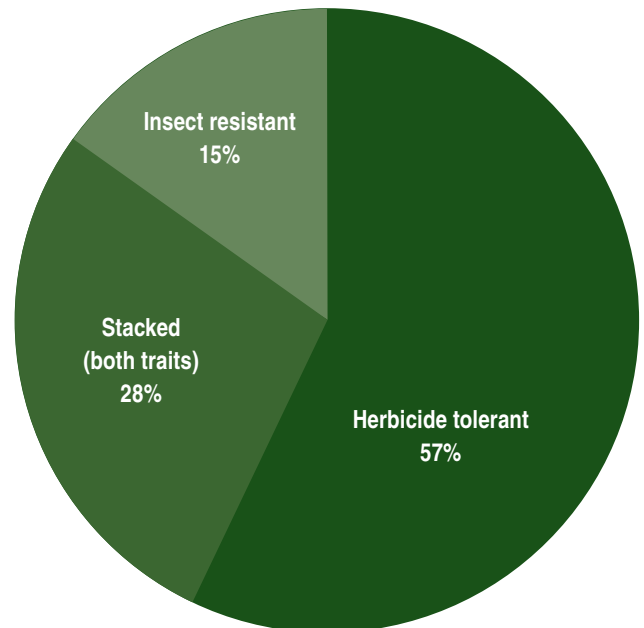
**Today, over 85% of the GM crops grown around the world are herbicide-tolerant.**<sup>3</sup> Most Ht crops on the market are genetically engineered to tolerate applications of glyphosate-based herbicides, such as Monsanto’s brand-name product, Roundup. When glyphosate was first introduced in the mid-1970s, it was used primarily to clear fields before planting or after harvesting corn or soy, and was often used with other herbicides.<sup>4</sup> However, the rapid spread of GM glyphosate-tolerant crops, along with a decrease in glyphosate prices since 1995, has meant that it is now the predominant agricultural herbicide, and in many cases has replaced a range of products.<sup>5</sup>

Other Ht crops are genetically engineered to tolerate glufosinate ammonium (such as Bayer’s Liberty herbicide). Ht corn and soy genetically engineered to tolerate the older herbicides 2,4-D and dicamba have also recently been approved in Canada, the US, Brazil and Argentina.

GM herbicide-tolerant crops were introduced in 1995 with a promise to create a more efficient system for herbicide application. This included

reducing herbicide use through lower application rates, fewer applications, and the use of herbicides such as glyphosate that “may be more benign than herbicides required for crops without herbicide-tolerant genes.”<sup>6</sup> Monsanto’s promise was that, “with the Roundup-resistant crops farmers will be able to target application more precisely and thus may use less herbicide overall.”<sup>7</sup> **However, the use of herbicides has increased with the widespread cultivation of GM herbicide-tolerant crops in North America, and some countries in South America.**

**Figure 2: GM traits as percent of total GM area**



**MAJOR GM TRAITS**

- Herbicide tolerance
- Insect resistance

**MINOR GM TRAITS**

- Virus resistance
- Drought tolerance



# Glyphosate

**G**lyphosate is the most widely used herbicide in the world today. It is a non-selective or broad-spectrum herbicide that is absorbed into the plant to kill it.

It was developed by the chemical company Monsanto (now the largest seed company in the world) and commercialized in the formula called “Roundup” in 1974. Monsanto’s patent for Roundup expired in 2000, but the market for Roundup has remained secure because of the widespread cultivation of Monsanto’s GM glyphosate-tolerant “Roundup Ready” seeds.

In the 1990’s, Monsanto commonly advertised Roundup as a herbicide with a “favourable environmental profile” that was “no more toxic to people and animals than table salt.”<sup>8</sup> However, in 1996, New York’s attorney general sued the company over “false and misleading advertising”. Monsanto was ordered to stop selling Roundup as “biodegradable,” and to pull ads claiming that it was “practically nontoxic,” and “stayed where you put it.”<sup>9</sup>

Roundup’s active ingredient is glyphosate, but, as with other herbicides, it also contains a number of other chemicals. **In March 2015, the World Health Organization’s International Agency for Research on Cancer determined that glyphosate is “probably carcinogenic to humans.”**<sup>10</sup>

## WHAT ARE THE ENVIRONMENTAL IMPACTS OF GLYPHOSATE HERBICIDES?

Monsanto’s product label notes that Roundup is toxic to aquatic organisms and instructs users to avoid direct applications to any body of water.<sup>11</sup> Glyphosate is highly soluble in water and can therefore move through aquatic systems. Its breakdown products are long-lasting in surface waters and highly toxic to aquatic life and amphibians.<sup>12</sup> Polyethoxylated tallow amine, the surfactant used in some glyphosate herbicide formulations, is highly toxic to amphibians and shellfish; it interferes with development, stunting growth and causing abnormalities in sex organs and tails in tadpoles.<sup>13</sup> A 2010 study observed malformations in frog and chicken embryos at dilutions of glyphosate at levels lower than those used in agriculture,<sup>14</sup> and a 2013 study concluded that its toxicity to aquatic invertebrates has been underestimated.<sup>15</sup> In 2012, the Environmental Commissioner of Ontario flagged an “emerging concern” about glyphosate’s impacts on aquatic ecosystems and amphibians.<sup>16</sup>

The Quebec government tested four rivers (in 2008, 2009, and 2010) and found the presence of many herbicides that, along with other factors, have diminished the biological diversity in those rivers.<sup>17</sup> In 2001, 65% of Alberta surface water samples contained pesticides; more than 75% of the samples contained two or more pesticides, and about 200 contained 6 or more pesticides.<sup>18</sup>

Glyphosate also reduces the biodiversity of soil microorganisms in the plant root zone.<sup>19</sup> Glyphosate can be broken down by microorganisms and can last for different lengths of time in soils, depending on the type of soil, and the kind and population size of soil microbes present. Roots of treated plants release glyphosate into the soil. Glyphosate also binds with certain soil minerals, such as magnesium, iron and potassium, making them less available for plant use.

*Some of this text is adapted from the National Farmers Union April 2015 factsheet on glyphosate.* <sup>20</sup>

## HERBICIDE-TOLERANT CROPS AND HERBICIDE USE IN CANADA

Almost all the GM crops currently grown in Canada — corn, soy, canola and sugar beet — are now herbicide-tolerant. This includes crops that are herbicide-tolerant (some to multiple herbicides) and those that are both herbicide-tolerant and insect-resistant. The Canadian government does not track how many hectares of GM crops are grown in Canada, where they are grown or what specific GM traits are in use. *For details on what GM crops are grown in Canada, and how much, see GMO Inquiry's report "Where in the world are GM crops and foods?"*

**Canada has not historically tracked pesticide use.**<sup>21</sup> This gap in information was critiqued by Canada's Commissioner for the Environment and Sustainable Development in 1999. The Commissioner reported to Parliament that, "without such data, Canada has no ability to accurately measure amounts of pesticides used and released into the environment. This information is needed to monitor the risks to health, safety and the environment."<sup>22</sup> Environment Canada echoed this assessment in a 1996 report: "the lack of more detailed data about pesticide production, use, emissions and effects over time represents a significant impediment to adequate tracking of these substances."<sup>23</sup>

In 2006, the federal government made it mandatory for companies to report their pesticide sales information.<sup>24</sup> Health Canada has since released annual reports on pesticide sales from 2008 to 2011. (The reports from 2012, 2013 or 2014 are not yet published). Because there is no reporting over the full twenty years of GM cultivation, or from the period before GM crops were in the fields, it is difficult to assess the impact of GM crops on pesticide use in Canada.

Despite this missing data, reports from Health Canada and information from other sources show that, **in general, pesticide use has increased significantly over the past twenty years.**

The United Nations Food and Agriculture Organization reports that 21.9 million kilograms of herbicides were sold in Canada in 1994.<sup>25</sup> Numbers from Health Canada's annual reports show that by 2011, this number had increased by 130% to 50.3 million kilograms.<sup>26</sup>

Similarly, numbers from the industry association CropLife Canada show that pesticide sales increased by 73% from 2001 to 2013, from \$1.27 billion to \$2.2 billion.<sup>27,28</sup>

**Glyphosate is the top pesticide ingredient sold in Canada, followed by 2,4-D and glufosinate ammonium.**<sup>a</sup> **Glyphosate use in Canada tripled between 2005 and 2011**, climbing from 30.2 million litres to 89.7 million in Western Canada, and from 3.8 million litres to 12.3 million in Eastern Canada.<sup>29</sup>

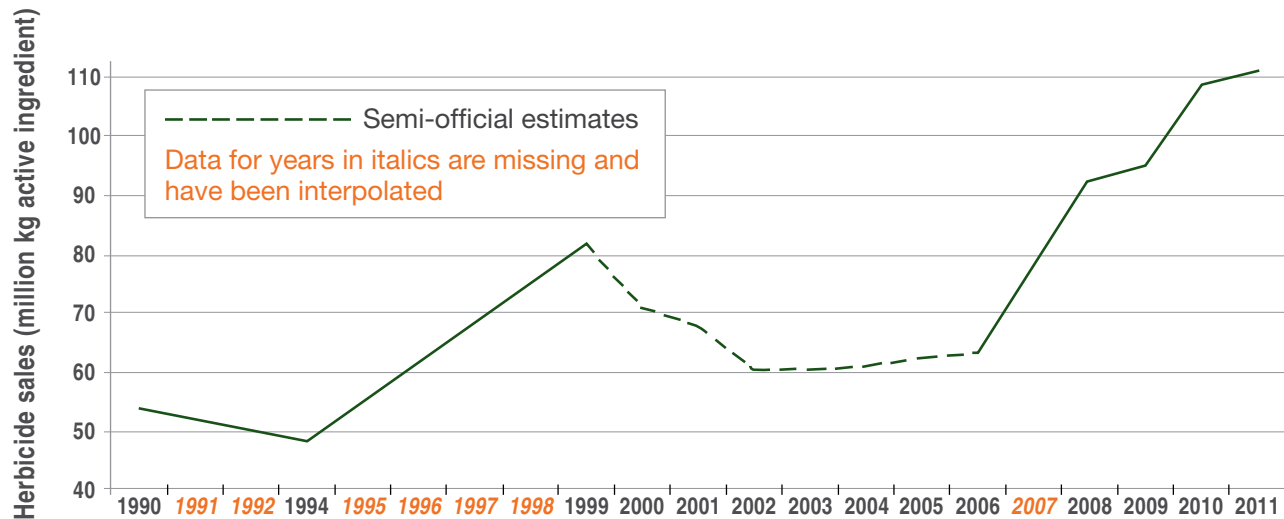
Increased pesticide use in Canada is not simply a result of increased cropland. The total land under crops in Canada increased very slightly from 34.9 million hectares to 35.3 million hectares between 1995 and 2011.<sup>30</sup> (Summerfallow land declined and the total area of farms also decreased.) The rise in pesticide sales in Canada is better explained by increasing "pesticide use intensity", or the amount of pesticide that is applied per hectare.

Not all provinces in Canada track pesticide sales or use. Alberta and Quebec track pesticide sales, and Ontario surveys pesticide use in agriculture.

The latest report from the Alberta government, on data from 2008, shows a substantial increase in glyphosate as well as 2,4-D (third most used) and glufosinate (sixth).<sup>31</sup> In 1998 glyphosate was already the most widely used pesticide in the province and the study concluded that, "The widespread use of glyphosate is attributable to the development of herbicide-tolerant canola varieties and its registered uses from pre-plant through to post-harvest application."<sup>32</sup> Glyphosate sales in Alberta rose by 27% from 1998 to 2003, and then by 84% from 2003 to 2008.<sup>33</sup> Glufosinate use also rose by 270% from 2003 to 2008. Overall agricultural pesticide use intensity was relatively consistent in Alberta between 1988 and 2003, fluctuating around 0.8 kilograms/

a Health Canada's reports do not specify exactly how much of each product was sold annually over the past years of reporting. The reports do, however, rank and divide various active ingredients into categories based on amounts sold. 2,4-D and glufosinate ammonium fall into the >1,000,000 kg category, while glyphosate is the only active ingredient in the >25,000,000 kg category.

**Fig. 3: Herbicide sales in Canada 1990-2011**



Data for 1990-2006 is from the UN Food and Agriculture Organization and data for 2008-2011 from Health Canada

hectare. By 2008 however, overall pesticide use intensity increased to over 1 kilogram/hectare, an increase of over 28% from 2003, mainly as a result of the increased sales of glyphosate products.<sup>34</sup>

In Quebec, sales of agricultural pesticides increased by 15% between 1995 (2.9 million kilograms)<sup>35</sup> and 2011 (3.3 million kilograms).<sup>36</sup> The Quebec government has also tested four rivers in areas where corn and soybeans are grown (2008-2010). The most frequently detected herbicides were S-metolachlor, detected on average in 99% of the samples; atrazine in 97%; glyphosate in 86%; imazethapyr in 79%; bentazon in 75%; and dicamba in 61%.<sup>37</sup> The 2010 report notes that the frequency of detection and the amount of glyphosate was higher than in previous study periods (2005-2007 and 2008-2010.) Twenty other herbicides, including 2,4-D, were also present at lower frequencies. “The statistical analysis shows a downward trend in the median concentrations of atrazine, S-metolachlor and dicamba, but an upward trend in the concentrations for glyphosate and imazethapyr. The presence and concentration of glyphosate continues to increase, and this phenomenon is linked to the increase in

glyphosate-tolerant genetically modified crops. The increase of imazethapyr is also linked to the expansion of soybean area.”<sup>38</sup>

Ontario’s 2008 survey shows that agricultural pesticide use in the province increased by approximately 15% and glyphosate use increased by approximately 76% from 2003.<sup>39</sup> The increase in glyphosate was attributed, in part, to the increased adoption of glyphosate-tolerant crops. Between 1993 (just prior to the release of GM crops) and 2008, glyphosate use in corn increased 30-fold, from 17,210 kilograms to 527,952 kilograms, and 7-fold in soybean, from 164,784 to 1.2 million kilograms.<sup>40</sup> In 2008, glyphosate accounted for roughly 55% of all active ingredients applied to Ontario’s crops.<sup>41</sup> Soybeans, corn and wheat in Ontario account for 64% of province’s crop land and 95% of glyphosate use.<sup>42</sup>

In 2012, the Environmental Commissioner of Ontario expressed concern over the long-term sustainability of the partnership of genetically modified crops and glyphosate herbicides, and recognized that the adoption of GE crops has resulted in “a huge increase in the application of glyphosate to agricultural soils.”<sup>43</sup>

## HERBICIDE-TOLERANT CROPS AND HERBICIDE USE IN THE US

Although we do not have consistent data for pesticide sales in Canada over the past 20 years of GM crop cultivation, data from the US and some countries in South America shows that herbicide use has steadily climbed as the area under GM herbicide-tolerant crops has increased.

Charles Benbrook's well-known study of data from the US Department of Agriculture analyses the overall changes in pesticide use on GM crop area in the 16 year period from 1996 - 2011.<sup>44</sup> He found that there was an initial reduction in total pesticide application in the US between 1996 and 2001 after GM crops were first introduced, but that this trend did not last. From 2002 onwards, overall pesticide use rose in the US. By 2011, total pesticide use was 24% higher per acre for GM crops than it was for non-GM crops.<sup>45</sup>

In particular, Benbrook found that GM herbicide-tolerant crops encouraged the increased use of chemical herbicides such as Monsanto's Roundup. Overall, herbicide use in US agriculture has increased by 237 million kilograms in the past 16 years.<sup>46</sup> Herbicide-tolerant soybeans accounted for 70% of the total increase. Herbicide use in Ht corn decreased slightly in the initial years after it was introduced, but has increased modestly since 2002.<sup>47</sup> The USDA echoes this conclusion: "Since 1996, the adoption of herbicide-tolerant corn, cotton, and soybeans has increased the use of glyphosate in place of other herbicides. This increase in glyphosate use, along with an increase in corn acreage, has increased total pesticide use since 2002."<sup>48</sup>

Benbrook concludes that this increase in herbicide use can be explained by two factors. One, farmers have cut down on the amount of low-dose non-glyphosate herbicides they use on their fields and replaced these chemicals with glyphosate, which is often applied frequently and needs to be applied in a higher dose.<sup>49</sup> Two, the spread of herbicide-resistant weeds is pushing up the use of herbicides (see page 13).

## HERBICIDE-TOLERANT CROPS AND HERBICIDE USE IN SOUTH AMERICA

A similar pattern of increased herbicide use can be seen in South America, where a large majority of soybean hectares are cultivated with GM herbicide-tolerant varieties. By 2010, 85% of the soybean crop planted in Brazil, Argentina and Bolivia was GM,<sup>50</sup> and by 2014, 95% of the soy grown in Paraguay, 100% in Uruguay and 83% in Bolivia was Ht.<sup>51</sup> Herbicide use, and glyphosate use in particular, has greatly increased as the area under GM soy have increased in these countries.

In Argentina, glyphosate use increased from 20-26 million litres per year in 1996-1999, to over 101 million litres by 2000.<sup>52</sup> By 2013, glyphosate use in Argentina was estimated to be 200 million litres.<sup>53</sup> All this increased volume of herbicide was applied on GM soy fields. By 2014, glyphosate-tolerant soybean accounted for 100% of total soybean hectares.<sup>54</sup>

In Brazil, the total volume of all pesticides sold rose by 360% between 2000 and 2009.<sup>55</sup> Herbicide use increased by 43% between 2006 and 2012 as the area planted with GM crops tripled, from 9.4 million hectares to 32 million hectares.<sup>56</sup> The average consumption of pesticide increased from approximately 7 kilograms a hectare in 2005 to 10.1 kilograms in 2011.<sup>57</sup> Soybean fields are the largest users of pesticides, and in 2010, 44% of the total pesticides in Brazil were applied to soybean fields. In the same year, 75% of soybean hectares were planted with Monsanto's glyphosate-tolerant "Roundup Ready" soybean. Today, approximately 93% of Brazil's soybean hectares are cultivated with GM varieties.<sup>58</sup> In 2012, Brazil surpassed the United States as the largest global buyer of pesticides.<sup>59</sup>

Similarly, in Uruguay, as the area planted with herbicide-tolerant soybean steadily increased from 1999 to 2010, the use of glyphosate also climbed, from 1.22 million kilograms in 1998, to 12.29 million kilograms by 2010.<sup>60</sup> In Bolivia, glyphosate use increased from 3.18 million litres in 2004 to 11.19 million litres in 2008.<sup>61</sup>

## Paraguay: the relationship between environmental, health and social impacts

The environmental impacts of GM cultivation are intimately connected with social, economic and health impacts, and can aggravate existing problems. In Paraguay, the impacts of intensive production of GM herbicide-tolerant soy include the increased loss of biodiversity, illness and deaths from pesticide poisoning, violent land evictions<sup>62,63</sup> and political unrest.<sup>64,65</sup>

80% of Paraguay's agricultural land is now in soy production, the highest proportion of all countries in South America.<sup>66</sup> Over 20 years, the area dedicated to soy has tripled, growing at an average rate of six percent every year.<sup>67</sup> 95% of this soy is Monsanto's Roundup Ready GM glyphosate-tolerant soy.<sup>68</sup> Paraguay, which is about the size of California, is now the world's sixth largest producer of soy, fourth largest exporter of soy, and eighth largest beef producer.<sup>69</sup> According to the US government, "Soybean production has changed Paraguayan agriculture."<sup>70</sup>

Paraguay's subtropical rainforest has been almost completely converted to agriculture and cattle grazing.<sup>71</sup> The expansion of soy cultivation has continued a trend of intensive deforestation and land conversion such that soy farms are commonly described as "green deserts."<sup>72</sup>

Every year almost 27 million litres of pesticides is used on soy production in Paraguay.<sup>73</sup> Pesticide poisoning is directly responsible for health problems in communities of small farmers who live adjacent to or are surrounded by large soy farms.<sup>74,75</sup> Two soy farm-owners were sentenced in 2005 for manslaughter in the pesticide-related death of 11-year-old Silvino Talavera.<sup>76</sup>

Paraguay has the second-fastest-growing economy in the world<sup>77</sup> but around half of the population lives in poverty.<sup>78</sup> Paraguay has the most unequal distribution of land in the world where 2.6% of the population owns 85.5% of the land. The expansion of GM soy, largely through large-scale farms including those owned by settlers from Brazil, is one of the main causes of land conflict in Paraguay and is taking land and livelihoods away from small-scale farmers. Rural and indigenous communities are frequently threatened with violent evictions from their land to make way for soy cultivation.<sup>79</sup>

"Ongoing human rights violations in Paraguay go hand in hand with the advancement of soy monocultures. Agribusiness corporations knowingly take advantage of the fact that in Paraguay corruption flourishes, while environmental regulations or human rights are not respected," said Javiera Rulli, a speaker in the 2008 public event series "Crops, Cars & Climate Crisis" organized by CBAN and other groups in the Working Group on Canadian Science and Technology Policy.

# THE EMERGENCE OF HERBICIDE-RESISTANT WEEDS

One of the consequences of the increased use of specific herbicides with GM Ht crops has been the emergence and spread of herbicide-resistant (HR) weeds, or “superweeds”. Continual use of certain herbicides puts selection pressure on weeds. This means that the most resistant weeds are the ones that can tolerate a herbicide application and, since they survive, they reproduce and pass this trait to future generations, spreading resistance. HR weeds may initially appear in just a few fields but resistance can spread through pollen and seeds.<sup>80</sup> According to University of Missouri weed scientist Kevin Bradley, “There’s not much we can do about pollen flying through the air, and that’s why we see such rapid spread of resistance.”<sup>81</sup>

The emergence of herbicide-resistant weeds predates GM crops. The first instances of herbicide-resistant weeds were observed in the 1950s<sup>82</sup> with the introduction and wider use of industrial farming methods and chemical herbicides. As herbicide use has increased, so has the number and range of herbicide-resistant weeds. **GM crops have accelerated and entrenched this pattern because the introduction of herbicide-tolerant crops, particularly glyphosate-tolerant “Roundup Ready” crops, has meant that large areas of cropland are repeatedly sprayed with the same herbicide.**

Glyphosate-resistant (GR) weeds emerged in GM glyphosate-tolerant crops just four years after their introduction.<sup>83</sup> These and other herbicide-resistant weeds are tracked on the International Survey of Herbicide Resistant Weeds, a database run by the Weed Science Society of America. Most of the documented cases of glyphosate-resistant weeds in the early 2000s were in fields of GM glyphosate-tolerant crops.<sup>84</sup> In the past twenty years, 32 species of weeds around the world have developed resistance to glyphosate. Most of these are found in just a few countries: 14 in the US, 10 in Australia, 7 in Argentina, 5 in Canada, and 6 in Brazil.<sup>85</sup>

**Over the past 20 years, weed scientists and environmentalists have repeatedly warned that Ht crops would lead to the emergence and spread of herbicide-resistant, and glyphosate-resistant weeds in particular.** In 1991, Jane Rissler of the Union of Concerned Scientists in the US had already concluded that, “Herbicide-tolerant crops perpetuate and extend the chemical pesticide era and its attendant human health and environmental toll,”<sup>86</sup> and in 1996, as the first GM Ht crops were being cultivated in Canada and the US, Margaret Mellon, of the same organization, predicted that, “Sooner or later weeds will begin to develop resistance to Roundup and more applications of herbicides will be required.”<sup>87</sup> In 2000/2001, environmental groups and scientists in Canada warned that this would happen.<sup>88,89</sup> More recently, Ontario government weed scientist Mike Cowbrough explained: “What we’re seeing with Glyphosate is what we’ve seen with every single herbicide that’s gone on the market – it gets used a lot because it works well and Mother Nature figures out a way to beat the system.”<sup>90</sup>

In 1997, Monsanto’s scientists said, “it is reasonable to expect that the probability of glyphosate-resistant weeds evolving will not increase significantly over that considered with current use.”<sup>91</sup> Ten years later, in 2007, Monsanto said that the use of Roundup herbicides and GM Roundup Ready crops in Eastern Canada “poses low risk for the development of glyphosate-resistant weeds when used in typical recommended Eastern Canadian crop rotations and when agronomic stewardship recommendations are followed. After over 30 years of use, there are no confirmed glyphosate-resistant weed species in Canada.”<sup>92</sup> The first glyphosate-resistant weeds began to emerge in Canada in 2008, and by 2010, Monsanto had started offering rebates to farmers who were using herbicides other than Roundup to control glyphosate-resistant weeds.<sup>93,94</sup>

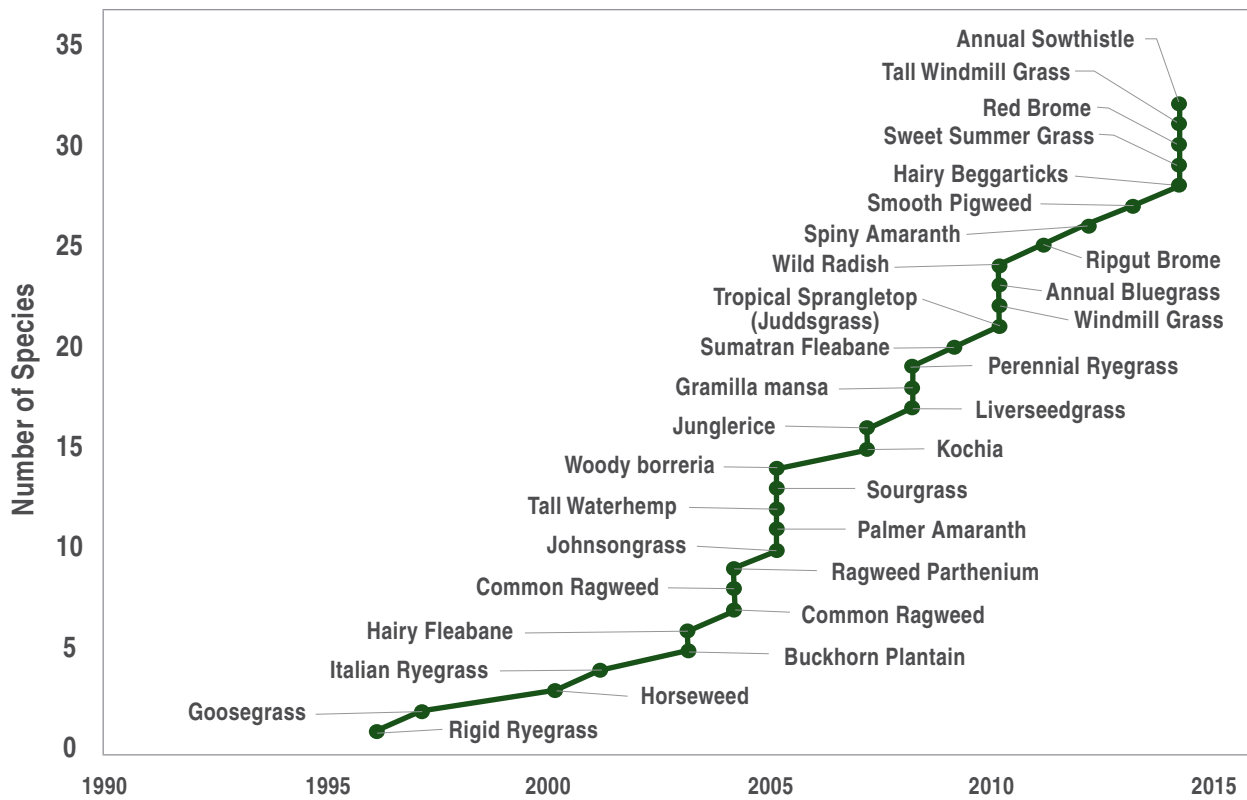
## HERBICIDE-RESISTANT WEEDS IN CANADA

There are five species of glyphosate-resistant weeds now found in Canada. An online survey of farmers in 2013 estimated that more than one million acres of Canadian farmland had glyphosate-resistant weeds growing on them.<sup>95</sup>

**Table 1: Glyphosate-resistant weeds in Canada<sup>96</sup>**

NAME	LATIN NAME	PROVINCE	DISCOVERED
Giant ragweed	<i>Ambrosia trifida</i>	Ontario	2008
Canada fleabane	<i>Conyza canadensis</i>	Ontario	2010
Common ragweed	<i>Ambrosia artemisiifolia</i>	Ontario	2012
Kochia	<i>Kochia scoparia</i>	Alberta, Manitoba, Saskatchewan	2012
Tall waterhemp	<i>Amaranthus tuberculatus</i>	Ontario	2014

**Fig. 4: Increase in glyphosate-resistant weeds worldwide**



Dr. Ian Heap, WeedScience.org, 2015

Both common ragweed and giant ragweed have been found to be resistant to glyphosate in Ontario, and both are often found in or near soybean fields.

GR Canada fleabane (also called horseweed, mare's tail, coltstail and butterweed) is the most widespread of the four glyphosate-resistant weed species found in Canada. It is also often found near glyphosate-tolerant soybean fields. Canada fleabane spreads fast, partly because it produces a very large number of seeds – up to 1 million per plant – that can travel long distances.<sup>97</sup> It was first found to have developed resistance in 2010 and has spread 800 kilometres in just four years.<sup>98</sup> In the 2013 online farmer survey, Ontario farmers estimated that 72,800 hectares of their farmland was infested with GR fleabane.<sup>99</sup>

Glyphosate-resistant kochia has been reported in Manitoba, Alberta and Saskatchewan, and scientists predict it could have a negative impact on crop yields.<sup>100</sup> Kochia can grow up to 6-8 feet, and glyphosate-resistant kochia can eventually destroy a crop.<sup>101</sup>

Glyphosate-resistant waterhemp is the most recently discovered glyphosate-resistant weed in Canada, and has been found to survive up to 6 times the normal application rate of glyphosate.<sup>102</sup>

Fewer glyphosate-resistant weeds have emerged in GM canola fields than in other GM crops. This is primarily because Ht canola is usually grown in rotation with other non-glyphosate-tolerant crops (more than with glyphosate-tolerant soy and corn, which are often grown in consecutive years [or back-to-back] in rotation). Additionally, unlike the other GM crops grown in Canada (corn, canola, and white sugarbeet) where the glyphosate-tolerant trait dominates, two Ht canola traits – glyphosate tolerance and glufosinate tolerance – are almost as commonly grown as each other.<sup>103</sup>

Glyphosate-resistant weeds are most widespread in the mid-western US, however weed scientists in the US are warning that these weeds are moving

northwards. They are encouraging Canadian farmers to watch their fields carefully and pull any resistant weeds that emerge by hand, in order to control resistant weeds before they spread.<sup>104</sup>

Fast-spreading weeds such as palmer amaranth, and large weeds such as kochia, may pose particularly severe problems for farmers in the US and Canada. Herbicide-resistant palmer amaranth has become a major problem for farmers in the US, and weed experts warn that it will be in Canada within the next two or three years.<sup>105</sup> Palmer amaranth can produce more than one million seeds per plant and spreads very fast. The seeds from a single glyphosate-resistant plant can completely take over small fields in just two years<sup>106</sup> and can cause 78% yield loss in soybean and 91% yield loss in corn.<sup>107</sup> Often, the spread of the weed can make the crop impossible to harvest, causing complete crop loss.<sup>108</sup>

There are two primary environmental impacts of Ht weeds. The first is that farmers often have to till to control weeds that cannot be controlled with herbicides, which leads to soil erosion (see box on page 26).<sup>109</sup> The second is that farmers continue to use glyphosate, because it is a broad-spectrum herbicide, but also add other herbicides to control glyphosate-resistant weeds.

The spread of each weed species differs based on its biology, and each requires a different response to control it. Because of this, the environmental impacts of controlling various GR weeds also vary, based on the herbicides themselves, the rate of application and each active ingredients' ecological and human health impacts. Because of how quickly it spreads, for instance, methods to control GR Canada fleabane are estimated to have a higher environmental impact than those to control GR common ragweed or giant ragweed.<sup>110</sup>

The Environmental Commissioner of Ontario has stated that, “emerging issues associated with the use of glyphosate raise significant questions with respect to the sustainability of the existing weed management paradigm.”<sup>111</sup>



“ In hindsight, they [regulators in Canada] could not have imagined the rapid, widespread adoption of glyphosate-resistant (GR) crops and subsequent chain of events: surge in glyphosate usage at the expense of other herbicides, sharp drop in investment in herbicide discovery, unrelenting rise of GR and multiple-HR weed populations, and increasing herbicide use in GMHR cropping systems. — Hugh Beckie and Linda Hall, 2014<sup>112</sup>

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## HERBICIDE-RESISTANT WEEDS IN THE US

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In 2013, the USDA estimated that 28.3 million hectares of US farmland were infested with glyphosate-resistant weeds.<sup>113</sup> Infestations in some cotton growing areas in the US were severe enough to force farmers to leave fields unharvested, and weed management costs in infested fields were 50-100% higher per hectare than in fields without glyphosate-resistant weeds.<sup>114</sup> According to third-party research conducted by the company Dow AgroSciences, cropland hectares with glyphosate-resistant weeds increased by around 50% in 2012, and around 80% over the last two years, to reach over 26.3 million hectares.<sup>115</sup> *The economic costs of herbicide-resistant weeds are examined in the GMO Inquiry report “Are GM crops better for farmers?”*

The spread of herbicide-resistant weeds, in turn, accounts for the bulk of increased use of pesticides in the US. Charles Benbrook estimated that the presence of resistant weeds drives up herbicide use by 25% to 50%.<sup>116</sup> He observes that related shifts in weed communities and the emergence of herbicide-resistant weeds have forced farmers to increase herbicide application rates, spray more often, and add other herbicides that work through an alternate mode-of-action. Benbrook concludes that, “Each of these responses has, and will continue to

contribute to the steady rise in the volume of herbicides applied per acre” on herbicide-tolerant GM corn, cotton, and soybean crops.<sup>117</sup>

This pattern is particularly visible in the US cotton belt, as herbicide use in cotton fields in the US has increased significantly and because herbicide-resistant weeds such as palmer amaranth have become a major problem in cotton fields. Two and a half times more active ingredient is now used on cotton fields in the US than was used before resistance emerged.<sup>118</sup> Six or seven herbicide ingredients may be used at the same time but resistant weeds cannot be controlled. Farmers are increasingly tilling their fields and hand weeding as well.

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## WEEDS WITH MULTIPLE RESISTANCES

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Because farmers are increasingly using mixes of different herbicides to control resistant weeds, a number of weeds have now developed resistance to multiple herbicides. In Canada, some glyphosate-resistant weeds have been found to be resistant to a class of herbicides called ALS inhibitors as well, and in the US, some GR weeds are resistant to two or three other herbicide classes. Tall waterhemp is the first broadleaf weed species that has been found to be resistant to all five classes of herbicides

in the US, and according to weed specialist Aaron Hager, it “has the potential to become an unmanageable problem.”<sup>119</sup>

In response to the problem of multiple resistance, Ontario’s agriculture ministry encourages farmers to use herbicides only when necessary, to use the recommended rates, to use herbicide mixtures that include two or more herbicide groups, and to rotate herbicides between herbicide groups.<sup>120</sup> The biotechnology industry similarly recommends that farmers use field management techniques such as rotating herbicides and crops, and also using herbicide mixes that have multiple ingredients and modes of action.<sup>121</sup>

However, the approach of using herbicide mixes merely increases the amount and number of herbicide ingredients being applied on fields. Additionally, the list of weeds that are resistant to herbicides is growing much faster than the list of new herbicides on the market.<sup>122</sup> Also, scientists have warned that increasing the intensity or frequency of herbicide applications on resistant weeds can increase the selection pressure, since they are the ones that can survive applications and multiply.<sup>123</sup> For example, some glyphosate-resistant weeds may need 8-10 times more herbicide to be controlled.<sup>124</sup> Relying on existing or new herbicides to solve the problem of resistant weeds is not a long-term, sustainable solution. According to Benbrook, “weed management experts are largely in agreement that the percent of cropland area planted to glyphosate-based HR [herbicide-tolerant] seeds must decline dramatically (e.g., by at least one-third to one-half) for farmers to have a realistic chance at success in preventing resistance.”<sup>125</sup>

“ Farmers are incorporating additional herbicides and other weed control methods in glyphosate-tolerant crops to gain control of herbicide resistant and tough-to-control weeds.

— Monsanto, 2014<sup>126</sup>

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## 2,4-D- AND DICAMBA-TOLERANT CROPS

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**Glyphosate-tolerant crops will soon reach the end of their use because of the emergence of glyphosate-resistant weeds.** With no new herbicides on the horizon, the seed and pesticide industry is encouraging farmers to use other herbicides and to adopt new GM Ht crops that are tolerant to older herbicides such as 2,4-D and dicamba (often these are stacked with tolerance to multiple herbicides). These tools threaten to replicate the problems created by the overuse of glyphosate in Ht cropping systems.<sup>b</sup>

Canada was the first country in the world, in 2012, to approve 2,4-D-tolerant crops (corn and soy developed by the company Dow AgroSciences), and dicamba-tolerant soy (developed by Monsanto). Dow has genetically engineered “Enlist” corn and soy to tolerate its “Enlist Duo” herbicide that combines glyphosate and 2,4-D choline. The Enlist

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<sup>b</sup> Many glyphosate-tolerant crops are already stacked with glufosinate, and future development is focused on stacking with four other classes of herbicides: Inhibitors of acetyl-CoA carboxylase (ACC), ALS inhibitors, HPDD inhibitors and synthetic auxins such as 2,4D and dicamba. (Green 2014 from Beckie and Hall 2014)

corn seeds will also be stacked with Monsanto's Roundup Ready Corn 2 and SmartStax.<sup>127</sup> Pending regulatory approval in China, the 2,4-D-tolerant corn has only been in limited production in Canada and the US, restricted to on-farm use for livestock feed,<sup>128</sup> and while Monsanto's dicamba-tolerant soy has been approved, it is not yet on the market.<sup>129</sup>

Weed scientists warn that the usefulness of the new herbicide-tolerant crops will be limited because there are already a number of weed species resistant to these older herbicides. There are 16 species of 2,4-D-resistant weeds around the world (four in the US and two in Canada)<sup>130</sup> and six species resistant to dicamba, (two in the US and two in Canada). Charles Benbrook has predicted that widespread use of 2,4-D-tolerant crops in the US could increase herbicide use by another 50%,<sup>131</sup> and lead to weeds developing resistance.<sup>132</sup> According to Canadian scientists Hugh Beckie and Linda Hall, "Cultivars with stacked-HR [herbicide-tolerant] traits (e.g., glyphosate, glufosinate, dicamba or 2,4-D) will provide a short-term respite from HR weeds, but will perpetuate the chemical treadmill and selection of multiple-HR weeds."<sup>133</sup> In 2012, the Environmental Commissioner of Ontario published an analysis that stated, "If these new GM plants are approved in Canada, Ontario may see a lot more 2,4-D applied to agricultural fields in years to come."<sup>134</sup>

## 2,4-D

2,4-D (2,4-Dichlorophenoxyacetic acid) was introduced in 1945 and is one of the world's oldest synthetic herbicides. It was a major ingredient in the defoliant Agent Orange, along with its chemically similar relative, 2,4,5-T. 2,4-D is already the second most used herbicide in Canada after glyphosate.

Due to manufacturing processes, 2,4-D is often contaminated with dioxins, a group of highly toxic chemical compounds that bioaccumulate in the food chain. The US Environmental Protection Agency reports that 2,4-D is the seventh largest source of dioxins in the US, while Environment Canada identified that phenoxy herbicides are the highest source of "lower chlorinated" dioxins in the environment.<sup>135</sup>

Adverse health effects may arise from 2,4-D itself, its breakdown products, dioxin contamination, or from a combination of these substances. The balance of epidemiological research suggests that 2,4-D can be persuasively linked to cancers, neurological impairment and reproductive problems.<sup>136</sup> 2,4-D has been found in urine and semen, and chlorophenoxy herbicides have been linked to sperm abnormalities, increased miscarriage rates, difficulties conceiving and bearing children, and birth defects.<sup>137</sup> The European Union Strategy for Endocrine Disruptors lists 2,4-D as a priority substance for further evaluation because it has at least some in vitro evidence of biological activity related to endocrine disruption.<sup>138</sup>

# INSECT-RESISTANT CROPS AND INSECTICIDE USE

The second major GM trait on the market in Canada and around the world is insect resistance. Biotechnology companies promised that, by genetically modifying crop plants to be toxic to certain pests, GM insect-resistant crops would reduce the amount of chemical insecticides added to the environment. However, this has not always been the case, and Bt crops have had a number of other environmental impacts.

Insect-resistant crop varieties are engineered with genes from the bacteria *Bacillus thuringiensis* (Bt) to produce Cry protein endotoxins in their cells. This makes the plant itself toxic to some above- and/or below-ground insects, such as butterflies and beetles. Different GM Bt events target different insects, and synthesize different amounts of the protein. For example, Bt corn varieties in Canada are engineered to variously target black cutworm, corn earworm, corn rootworm, European corn borer, fall armyworm or the western bean cutworm.<sup>139</sup> Many varieties are now “stacked” with several Bt events. For example, Monsanto’s “Smartstax” corn has six Cry proteins (as well as two herbicide-tolerant traits) and therefore produces a much larger amount of the endotoxin than other single-event varieties.

The Canadian government has not tracked or monitored the impact of Bt crops on insecticide use. However, **the use of Bt crops in the US has decreased the use of insecticides.** Charles Benbrook’s study found that Bt corn reduced pesticide use by 41 million kilograms, while Bt cotton reduced it by 15 million kilograms.<sup>140</sup> Together, this accounts for a reduction of 56 million kilograms of insecticides.

However, this finding does not represent the full reality of pesticide use with Bt crops. Bt plants themselves produce a toxin that may have adverse environmental impacts, including on soil and non-target organisms. Benbrook estimates that the amount of Bt toxin produced by Bt corn varieties that target the European corn borer is almost as much, or as much, as the average rates of external insecticide application.<sup>141</sup> For GM events that target corn rootworm, the amount of toxin the plants produce is much higher than the average application of insecticides would be. Additionally, Monsanto’s “SmartStax” corn produced approximately 19 times the average conventional insecticide rate applied in 2010, in the US.<sup>142</sup> The report *GMO Myths and Truths* concludes that **Bt crops, “simply change the type of insecticide and they way in which it is used — from sprayed on, to built in.”**<sup>143</sup>

The use of Bt crops can lead to new problems such as the emergence of new, secondary pests. For example, in India the cultivation of Bt cotton led to an initial reduction of its target pest species but that decline then allowed for the emergence of secondary pests which had not been a significant threat to cotton crops until then. For example, mealybugs, aphids and thrips now pose new serious problems for cotton farmers across India and require control via the use of insecticides.<sup>144,145</sup> In addition, after a few seasons of exposure to Bt cotton, some bollworm species developed resistance, in India and other GM cotton growing countries.<sup>146,147</sup> While pesticide reduction was the primary selling point for Bt cotton adoption in India, recent studies have found that overall pesticide use has not decreased in any state that grows Bt cotton, with the exception of Andhra Pradesh.<sup>148</sup>

## THE EMERGENCE OF BT-RESISTANT INSECTS

As is the case with herbicide-resistant weeds, insect pests have also developed, and will continue to develop, resistance to the toxins in GM insect-resistant crops. Scientists predicted the likelihood of insects developing resistance to Bt crops as early as 1994.<sup>149</sup> A number of insects are now resistant to several Bt crop varieties, with cases documented in the US in Bt corn, and in India, South Africa, Brazil and China in Bt cotton. Insect resistance to Bt crops appears to be spreading; in 2005, one insect species had documented resistance and by 2010, five out of 13 studied species were found to have evolved resistance.<sup>150</sup>

**We have not seen Bt-resistant pests in Canada yet.**<sup>151</sup> However, Canada has a number of similar crop pests to those found in the US, such as the Western corn rootworm and European corn borer (ECB), and much of the GM grain corn we grow in Canada is stacked with a Bt trait. However, this Bt corn is grown on fewer hectares in Canada than in the US. Researchers in Canada have warned that there is no reason resistance could not develop in insects in Canada as well, if the use of Bt crops continues.<sup>152,153</sup> The Canadian Food Inspection Agency (CFIA) acknowledges this possibility, and states that, “resistance to the B.t.k. proteins could also develop following continued exposure to ECB-resistant hybrid corn.” The CFIA also says that “it is very difficult .... to predict the extent and rapidity of resistance development without field validation...plants should therefore be responsibly managed...”<sup>154</sup>

Bt, which refers to the bacteria *Bacillus thuringiensis*, is commonly used as a foliar spray but Bt crops that are engineered to produce the Bt toxin have a bigger environmental impact than externally applied Bt sprays for a number of reasons. These include the fact that Bt plants produce much higher levels of the toxin than are used in foliar sprays, this toxin is less selective than sprays, and because foliar applications are very short lived in the environment.<sup>155</sup>

The toxins released by Bt crops, on the other hand, persist in the environment and continue to be released from Bt crop roots for the entire growing season. Along with the impacts that this can have on soil and other non-target organisms, this high-level, prolonged exposure greatly increases the risk of insects developing resistance. Scientist Ann Clark concludes: “the process of engineering insecticidal traits into crop plants has taken a product that was short-lived and selective in its native state and turned it into a product that mirrors the persistent, bioaccumulative, ramifying harms associated with chemical insecticides.”<sup>156</sup> In its summary of its decision to approve a Bt corn, the CFIA acknowledges that “target insects will thus be exposed to significantly higher levels of B.t.k. than through the current foliar spray treatments, leading to high selection pressures for resistant ECB individuals.”<sup>157</sup>

Along with making Bt crops useless to farmers in Canada, Bt resistance could also mean that ecological and organic farmers who use foliar Bt to control pests will not be able to do so.<sup>158</sup>

While no pest resistance incidents have been confirmed in Canada, the spreading resistance in the US is a warning. Reports of Bt-resistant corn rootworm began to emerge in the corn belt of the US in 2009,<sup>159</sup> and they have now been observed in several parts of the US. Insects that survive in Bt fields go on to multiply, passing down the ability to withstand the toxin to future generations. Continuous exposure to the toxin perpetuates this evolutionary cycle and populations of resistant insects grow.

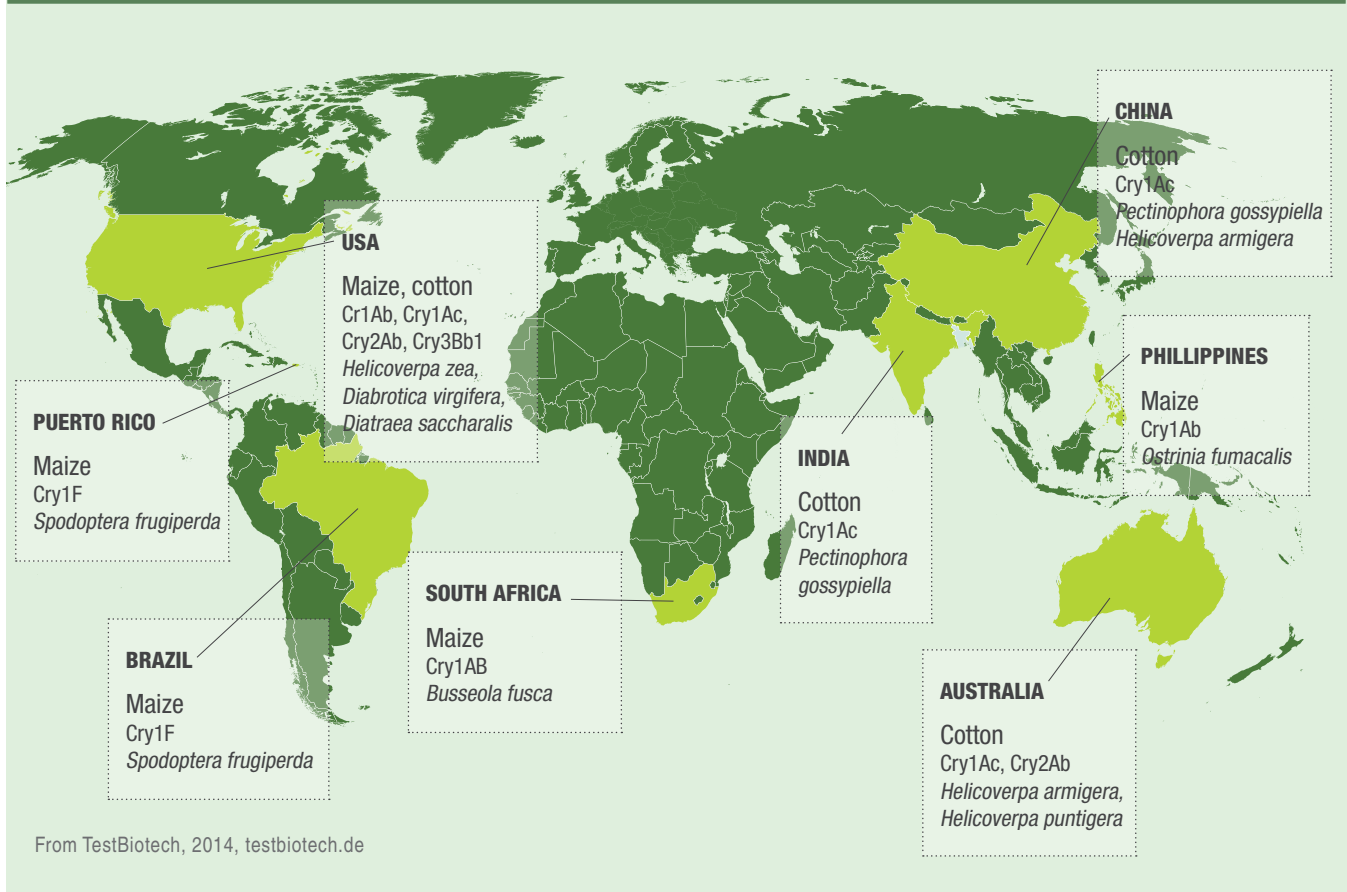
In 2014, researchers found that armyworms in the US were also showing resistance to Cry1F protein in some Bt corn.<sup>160</sup>

Different insects react differently when continually exposed to toxins. The corn borer, for instance, has remained susceptible to the Bt toxin in the US, while the rootworm began to show resistance early on. This was predictable. Scientists knew that the rootworm is prone to developing resistance due to its mating patterns and the fact that it has developed resistance to other pesticides in the past.<sup>161</sup>

Pest resistance to Bt crops has emerged in other countries as well. In India, the pink bollworm has developed resistance to Monsanto's first generation Bt cotton, Bollgard I.<sup>162</sup> In response, Monsanto released a second generation Bt cotton with two

Bt proteins, called Bollgard II. In South Africa, scientists found that the maize stalk borer has developed resistance to the Cry1Ab protein in Bt corn,<sup>163</sup> and in Brazil, the fall armyworm has developed resistance to the Cry1F protein in Bt corn.<sup>164</sup>

**Figure 5: Bt-resistant insects across the globe**



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## DELAYING BT-RESISTANT INSECTS IN CANADA

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The development of insect resistance was predicted. In Canada, in 1998, the industry Corn Pest Coalition developed a management plan to “reduce and delay the development” of resistant populations of European Corn Rootworm.<sup>165</sup> This plan focused on guidelines for farmers to provide non-Bt areas called refugia, or refuges, where non-resistant insects could continue to mate with resistant insects from nearby Bt corn fields, preventing a resistant population from spreading. A refuge is a block or strip of crops that does not contain a Bt trait. In Canada, refugia guidelines were set at 20% of the crop. In the US, 20% for corn was also decided, despite the recommendation of 50% from the Environmental Protection Agency’s Scientific Advisory Panel.<sup>166</sup> In 1997, Canadian scientist Ann Clark referred to these management plans as ecologically implausible.<sup>167</sup>

The refugia requirement is set out by the government but monitoring and enforcement is the responsibility of companies. In 2009, refugia compliance in Canada’s cornfields was down to 61% from 81% in 2005.<sup>168</sup> By 2010 Monsanto said it would give corn growers one warning to keep refugia at 20%.<sup>169</sup> In 2011, the US Environmental Protection Agency stated that Monsanto’s strategy for monitoring resistance in the US was “inadequate and likely to miss early resistance events.”<sup>170</sup> By 2013 refugia compliance levels in Canada were high because of the new option of “Refuge in the Bag” where the non-Bt corn seed was mixed in the bag of seed, at a lower 5%.

This reduction of refugia size from 20% to 5% was justified by the development of Bt crops that produce two or more Bt toxins to kill the same pests. The theory is that two different proteins can work on the same bug in two different ways and thus reduce the probability of resistance developing. According to Monsanto, the multiple Bt genes, or modes of action, “provide additional protection and effectively reduce the likelihood of insect resistance developing.”<sup>171</sup> This was the case with the introduction of Monsanto’s SmartStax corn (2010) that has six Bt toxins (and two herbicide-tolerant traits) and is sold with “Refuge in a Bag”.

However, scientists believe that when insects resistant to one toxin are exposed to these crops, they develop resistance to the second toxin even faster.<sup>172</sup> Planting crops with multiple Bt toxins may speed up resistance, instead of slowing it down. Laboratory studies indicate that, for instance, that rootworm resistant to the toxins in Monsanto’s Bt corn (Cry3Bb1) may also be resistant to those in Syngenta’s Bt corn (mCry3a).<sup>173</sup> A meta-analysis led by the University of Arizona found that in about half the cases, the actual efficacy of the multiple toxins against pests did not live up to expectations. Resistance to one toxin often caused cross-resistance to another toxin.<sup>174</sup> These findings mean that the reduced size of refuges may be a mistake.

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## GM CROPS AND THE PESTICIDE TREADMILL

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Widespread use of herbicide-tolerant crops over the past 20 years has led to an increased use of herbicides. Continual exposure to these herbicides has led to the emergence of herbicide-resistant weeds. The spread of these herbicide-resistant weeds is, in turn, further pushing up the overall use of herbicides.<sup>175</sup> A similar pattern has developed in Bt insect-resistant crop cultivation systems. This pesticide treadmill has serious impacts for the environment and human health.

Industry responses to weed and insect resistance problems focus on replacing one pesticide with another and on replacing GM seeds with other seeds that are genetically engineered to be tolerant to other herbicides and to produce multiple Bt toxins. However, this approach merely replaces one failing technology with another, short-term, application, and does not address the environmental impacts of either. Weed scientists are warning that “there is evidence that history is repeating itself.”<sup>176</sup> Farmers are beginning to rely on glufosinate-tolerant crops to control glyphosate-resistant weeds, and weed scientists warn that the introduction of new GM Ht crops will repeat the cycle of increasing herbicide use and weed resistance, while providing, at best, a short-term approach to managing herbicide-resistant weeds.

Experts have repeatedly told us that the real solution lies in reducing herbicide use and the use of GM herbicide-tolerant crops. Beckie and Hall, for instance, conclude that, **“The only sustainable solution is for government or end-users of commodities to set herbicide-use reduction targets in our major field crops similar to European Union member states, and include financial incentives or penalties in agricultural programs to support this policy.”**<sup>177</sup> According to Charles Benbrook, “weed management experts are largely in agreement that the percent of cropland area planted to glyphosate-based HR seeds must decline dramatically (e.g., by at least one-third to one-half) for farmers to have a realistic chance at success in preventing resistance.”<sup>178</sup>

**SEEDS:** The world’s top three corporations control over half (53%) of the world’s commercial seed market; the top 10 control over three-quarters (76%).

(ETC Group, Putting the Cartel Before the Horse, 2013)

**PESTICIDES:** Six companies hold 76% of the global agrochemical market. The top ten pesticide companies control almost 95% of the global market.

(ETC Group, 2013)

**Table 2: Top seed and pesticide companies**

	COMPANY	SEED REVENUE [\$MILLION]	COMPANY	AGROCHEMICALS REVENUE [\$MILLION]
1	Monsanto	10,740	Syngenta	11,381
2	DuPont	7,913	Bayer	10,257
3	Syngenta	3,155	BASF	7,243
4	Vilmorin	1,995	Dow Chemical	5,686
5	Dow Chemical	1,604	Monsanto	5,115
6	KWS	1,567	DuPont	3,391

Source: Monsanto’s Bid For Syngenta Means A Shift In Strategy May. 11, 2015  
<http://seekingalpha.com/article/3167256-monsantos-bid-for-syngenta-means-a-shift-in-strategy>



# GM CROPS AND BIODIVERSITY

**B**iological, ecological and social systems are interrelated and interdependent. Understanding how the release of GMOs affects all these systems is complex, particularly because there may be a time lag between the release of a GMO into the environment, and any observable impacts.<sup>179</sup> As scientist Katherine Barrett has explained, “We are dealing with highly complex, variable and interdependent systems that do not lend themselves to simple cause-and-effect explanations or isolated experimentation. In fact, complexity and irresolvable uncertainty are now recognised principles of ecosystems-based management.”<sup>180</sup>

The full impacts on the environment cannot be predicted. The potential environmental impacts of releasing GM crops and trees into the environment are currently assessed through government-regulated field trials. Fundamentally, however, field and laboratory tests are limited tools for predicting the interactions and impacts of GM crops in the environment. Department of Fisheries and Oceans researcher Robert Devlin, for example, created semi-natural stream tanks in the laboratory to examine the possible ecological impacts of GM salmon escape. He observed changed behaviour in the GM salmon.<sup>181</sup> However, Devlin additionally says, “But our research has also shown the limitations of laboratory research for risk assessments. We can’t release genetically engineered fish into the wild and monitor them; that would be too risky. But we’re also unable to accurately re-create an ocean or river in the lab. That means we are finding it difficult to predict with confidence what would happen with genetically engineered salmon in nature, with all its variables.”<sup>182</sup>

The only experiment that will reveal the true impacts of GMOs is open-air release.

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## HERBICIDE-TOLERANT CROPS AND IMPACTS ON BIODIVERSITY

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Over twenty years, the cultivation of herbicide-tolerant crops has had several impacts on biodiversity. The impacts largely result from the expansion of monocultures as well as the increased use of certain herbicides. Different herbicides have varying impacts on biodiversity, based on their properties as well as the rates and ways in which they are applied. Overall, however, Ht crop systems have encouraged the use of herbicides that reduce overall plant diversity in agricultural systems, and in doing so, can limit habitat and food sources for other important organisms such as bee and butterfly species.

In 2001, the Royal Society of Canada’s Expert Panel on the Future of Food Biotechnology pointed out that “agricultural land in North America is also important for wildlife.” The Panel concluded that, **“conserving biodiversity is an essential part of sustainable agriculture that is beneficial from both an economic and ecological perspective.”**<sup>183</sup>

Studies show that some agriculture systems support more biodiversity than others. When researchers at Simon Fraser University in BC compared GM herbicide-tolerant canola, conventional canola and organic canola fields in Alberta, for instance, they

found that wild bee populations were largest in organic systems and least abundant in GM systems.<sup>184</sup> Furthermore, the pollination deficit (the difference between potential and actual pollination) was greatest in the GM fields, while there was no pollination deficit at all in organic fields.

The lower bee abundance in those GM fields studied may be explained, in part, by the fact that fields of herbicide-tolerant crops often have lower weed and other plant diversity, which in turn reduces food sources for a number of species, including important pollinators.<sup>185</sup> The Farm Scale Evaluations conducted in the United Kingdom in the early 2000's to compare GM and non-GM conventional farming echoed this possibility.<sup>186</sup> The study found that weed diversity and biomass, as well as farmland diversity including bee numbers, were lower in the herbicide-tolerant canola and sugar beet trials than in the non-GM fields.<sup>187</sup> This study points to important implications about the impact of herbicide-tolerant GM crops on biodiversity widely. After the study was published, the UK government announced that it would not approve herbicide-tolerant canola or sugar beet for commercialization.<sup>188</sup> Both of these crops are grown in Canada.

Reduced weed diversity in Ht systems has had a very direct impact on the Monarch butterfly. Monarchs are famous for their long migration from Eastern Canada and the US to Central Mexico. On their flight back north, the butterflies stop to breed in the southern and Mid-western US, before future generations continue northward, some travelling as far as Canada. Monarchs have specific needs during this time: The butterfly lays its eggs exclusively on some species of milkweed, and monarch caterpillars eat only milkweed leaves. Monarchs have co-existed within agricultural ecosystems throughout the past century, until the introduction of GM glyphosate-tolerant crops.

**Over the past 20 years, monarch butterfly populations in North America have fallen by 90%.** A critical reason for their dramatic decline has been the reduction in milkweed populations, especially in monarch breeding grounds in the US corn-belt, because of the widespread use of glyphosate on and around fields of Ht crops. This diminishing habitat essentially deprives monarchs of their ability to breed.

Glyphosate is one of the few herbicides that kills common milkweed. Over the past two decades, as glyphosate use on corn and soy fields in the US has increased 20-fold, corn and soy fields in the corn belt have lost 99% of their milkweed.<sup>189</sup> The impact of glyphosate is particularly severe when used with glyphosate-tolerant crops. It is used more frequently and at higher rates than with non-GM crops, and usually applied later in the season when milkweed is flowering. When glyphosate-tolerant crops are grown back to back, as they often are with glyphosate-tolerant corn and soy, milkweed populations are unable to recover.

The report *Monarchs in Peril* from the US Center for Food Safety details the impacts of glyphosate-tolerant crops on monarch habitat and populations. The report concludes that, "Monarchs are in imminent danger unless milkweed is restored to Midwestern crop fields. Milkweed cannot recover with continued heavy use of glyphosate on Roundup Ready crops."<sup>190</sup>

Plans to introduce other GM crops that are tolerant to glyphosate as well as to 2,4-D and/or dicamba mean that glyphosate use will continue, while the use of 2,4-D and dicamba is predicted to rise. Adult monarch butterflies feed on nectar, and both 2,4-D and dicamba threaten to reduce populations of nectar plants near fields.

# What is organic farming?

Organic farming uses an ecological approach and follows specific practices stipulated in the Canada organic standard. Certified organic farmers are inspected every year by professional inspectors from third-party certifying organizations to make sure that they are following the standard.

The preamble to the national standard describes organic production as based on principles that support healthy practices. “These principles aim to increase the quality and the durability of the environment through specific management and production methods. They also focus on the humane treatment of animals.”<sup>191</sup>

The general principles of organic production include the following:

- 1 Protect the environment, minimize soil degradation and erosion, decrease pollution, optimize biological productivity and support a sound state of health.
- 2 Maintain long-term soil fertility by optimizing conditions for biological activity within the soil.
- 3 Maintain biological diversity within the system.
- 4 Recycle materials and resources to the greatest extent possible within the enterprise.
- 5 Provide attentive care that promotes the health and meets the behavioral needs of livestock.
- 6 Prepare organic products, emphasizing careful processing, and handling methods in order to maintain the organic integrity and vital qualities of the products at all stages of production.
- 7 Rely on renewable resources in locally organized agricultural systems.<sup>192</sup>

Among other requirements, the organic standard makes sure that certified organic farmers do not use:

- Genetically modified seeds or animal feeds;
- Synthetic pesticides (including fungicides, insecticides, and herbicides);
- Synthetic fertilizers;
- Animal feed made with animal waste or slaughter by-products;
- Synthetic hormones, antibiotics or other animal drugs to stimulate growth or production of livestock;
- Sewage sludge (recycled human waste) or waste from intensive livestock operations and biosolids (water waste from industry) on their land.

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## HERBICIDE-TOLERANT SYSTEMS AND SOIL CONSERVATION

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One of the advertised benefits of using Ht crops is to allow farmers to use no-till management systems, which are better for the environment because they prevent soil erosion and preserve organic matter. Herbicide-tolerant cropping systems replace tilling the soil to remove and kill weeds, with the use of herbicides. Such no-till practices therefore encourage herbicide use, and the fact that weeds are not removed or killed by tilling, can encourage the emergence of herbicide-resistant weeds.<sup>193</sup> One review of a number of reports of glyphosate-resistant weeds concluded that, “adoption of a no-till seeding system...allowed resistance to emerge...glyphosate-resistant weeds can evolve where there is insufficient diversity in weed management systems.”<sup>194</sup>

Furthermore, experts are now telling farmers that one way to control extreme weed resistance is by deeply tilling their fields.<sup>195</sup> For instance, farmers in Saskatchewan who have not tilled their fields in years, have had to till to get rid of glyphosate-resistant kochia that had advanced past the stage when it could be controlled by herbicide applications.

**The advantage that Ht systems may have offered in terms of soil conservation are being quickly overturned by the emergence of glyphosate-resistant weeds that cannot be controlled by herbicides, leaving farmers to resort to tilling.**

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## BT CROPS AND BIODIVERSITY

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The impact of Bt crops on non-target organisms<sup>c</sup> is not entirely clear, and scientists disagree on whether the Bt toxin that GM Bt plants produce should be counted as “applied insecticide.”<sup>196</sup> Benbrook argues that Bt toxins produced by GM plants should be included in calculations of pesticide use, and some studies have shown that Bt crops may pose a number of risks to some beneficial insects and soil organisms.

In 2007, for example, researchers at Indiana University found that Bt corn had a detrimental impact on freshwater ecosystems.<sup>197</sup> Pollen, leaves and other parts of GM Bt corn plants reached streams near fields, and were consumed by insects, such as caddisflies, that were living in those streams. In related laboratory studies, the researchers found that eating Bt corn litter significantly decreased growth rates and increased the mortality rates of caddisflies.<sup>198</sup>

Studies have also indicated negative impacts on other non-target insects, such as Monarch butterflies,<sup>199,200</sup> swallowtail butterflies<sup>201</sup> and ladybirds.<sup>202</sup>

Scientists have also observed that Bt crops can negatively affect soil organisms, many of which are important for soil health and to help plants absorb nutrients from the soil and to resist disease. Non-GM corn plants, for example, have been found to have higher levels of micorrhizal and arbuscular mycorrhizal fungi than GM corn.<sup>203,204</sup>

Bees, both native bees and honeybees, are particularly important for agriculture because they are the major pollinators of a third of the crops we eat. A major threat to bee health is the use of a group of pesticides called neonicotinoids, which are widely used, usually as seed treatments, on both GM and non-GM crops.<sup>205</sup> However, Bt crops may also pose a particular risk to bees. One study found that exposure to the Cry1Ab protein (found in Bt crops) disturbed honeybees’ learning performance, which can impact their ability to forage efficiently<sup>206</sup> and can also negatively affect their food consumption. The specific impacts of GM crops on bees and other pollinators and beneficial insects needs to be investigated in greater detail.<sup>207</sup>

GM crops – both Ht and Bt crops – are often grown as monocultures. The four major GM crops being grown around the world are all large-scale field crops (corn, canola, cotton, and soy), which are cultivated on large tracts of land, usually in rotation with just one other crop. This system increases the presence of the pests that target that particular crop.

In addition, GM monocultures have displaced other important land uses in some parts of the world. In South America, for example, large-scale cultivation of GM herbicide-tolerant soy has taken over forestland, as well as other important agricultural and non-agricultural landscapes.<sup>208</sup>

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<sup>c</sup> Organisms that are not targeted by the Bt toxin or Bt plants.

# GM CONTAMINATION

**G**ene flow via seeds and pollen can be hard to control. GM contamination can occur through any number of ways, including through human error. Over the past twenty years in Canada, there have been many cases where genetic material from GM crops has mixed with non-GM crops and foods.

Each GM crop and animal has a different contamination potential, based on its biology and use, with different potential ecological impacts. The ecological risks associated with gene flow need to be assessed carefully with each GMO because contamination is likely, and in some cases is inevitable.

**Genetic pollution from GMOs cannot be controlled or reversed. It is living pollution that self-replicates.**

Canadian scientist Rene Van Acker argues that there are two lessons relating to the movement of GM material that we have learned from our experience with GM crops in North America: “When GM crops are grown outside at a commercial scale, the movement of GM traits beyond their intended destinations can be expected and the risk of escape increases with the scale of production, and full retraction of escaped GM traits is very difficult and may be impossible if escape is into a broader agricultural supply chain.”<sup>209</sup>

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## GM CONTAMINATION IN GLOBAL CENTRES OF BIODIVERSITY

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The impacts of contamination are particularly profound in global centres of origin and centres of diversity of particular crops (the areas where our major food crops originate or where genetic diversity is greatest). Mexico, for instance, is the center of origin for corn (maize), and is home to a vast diversity of corn landraces. Such diversity is key to maintaining resilient crops that are adapted to a wide range of conditions, and to breeding new adaptive varieties.

In 2000, researchers from the University of California Berkeley found native Mexican landraces of corn in Oaxaca contained significant contamination from GM varieties.<sup>210</sup> Although there had been a moratorium on growing GM corn in Mexico since 1998, GM corn was still making its way across the border from the US. In 2001, a Mexican government study corroborated this evidence.<sup>211</sup> At the time, the Secretary of Mexico’s National Biodiversity Commission said, “This is the world’s worst case of contamination by genetically modified material because it happened in the place of origin of a major crop.”<sup>212</sup>

In subsequent years, GM contamination was one of the types of environmental damage most commonly reported to the Mexican Chapter of the Permanent Peoples’ Tribunal. The tribunal concluded that, “Given the very serious risks threatening the global centre of origin of maize, the staple of the peoples who created it for the good of humanity as a whole, and since Mexico is the gene pool of this pillar of world food security, it should prohibit the sowing of genetically modified maize in Mexico.”<sup>213</sup> In 2015, a string of court decisions halted the approval of new GM maize plantings in Mexico.<sup>214</sup>

Concerns about preserving genetic diversity were also central to the decision to establish a 10-year moratorium on GM cultivation in Peru in 2011, after potato farmers first achieved a ban on GM potatoes in the state of Cusco.<sup>215,216</sup> Similarly, in 2009, the Indian government placed an indefinite moratorium on the release of GM Bt eggplant in India. One of the main reasons for this decision was the fact that India is the centre of origin for eggplant, and concerns that the release of GM eggplant posed a risk to the rich diversity of Indian varieties.<sup>217</sup>

Gene flow can also take place from GM crops to wild and weedy crop relatives. Different species and traits will be able to survive and persist in the wild with varying degrees of success.<sup>218</sup> In China, for example, researchers have determined that, if herbicide-tolerant rice was released, transgenes from the GM rice could be expected to spread to

wild and weedy rice within a few seasons of contact, and may have unknown ecological consequences.<sup>219</sup>

## GM CONTAMINATION IN CANADA

Contamination from GM crops, and experimental GM animals,<sup>220</sup> has occurred in Canada. Such incidents can have important environmental, health, social and economic impacts. In Canada, the impacts have included the contamination of seed stocks, with the consequences of diminished seed diversity and costs to farmers.

Contamination from GM flax is one such example.<sup>d</sup> In 2009, Canada's exports of flax to Europe were shut down by contamination that reached 35 countries.<sup>221</sup> Flax farmers had to test their farm-saved seed, and if the GM trait was found, purchase new seed. As well as costs to farmers, this incident reduced genetic diversity in Canada's flax varieties.

Organic farming prohibits the use of GM seed. Organic grain farmers in Canada have largely stopped growing canola due to contamination from GM canola. Once GM canola was introduced in Canada, seed contamination quickly became an issue.<sup>222</sup> Ultimately, except in a few isolated areas where other farmers do not grow canola, certified organic farmers have lost the ability to grow, sell and export organic canola. Such GM contamination threatens the future of organic farming, and in doing so, threatens the future of a regulated ecological production model.

Field tests of GM crops and trees also pose contamination risks. In 2013, the *Ottawa Citizen* reported a major containment breach of GM wheat research trials at Agriculture Canada's Ottawa Experimental Farm by a flock of Canada Geese. The geese landed at the field trial site in the summer of 2012, ate the GM wheat growing there, and then flew away, possibly spreading viable undigested GM wheat seed through their droppings.<sup>223</sup>

*The economic and social costs of contamination, including the consequences of GM flax and canola contamination in Canada, will be examined in the GMO Inquiry report "Are GM Crops Better for Farmers?"*

## Terminator Technology

Genetic Use Restriction Technology (GURTs) or "Terminator Technology" genetically engineers seeds to be sterile at harvest. It was developed as a biological mechanism to stop farmers from saving and re-planting patented seed but some argue that this technology could be used to prevent contamination from GM plants and trees. There is, however, an international moratorium on the commercialization and field-testing of Terminator at the United Nations Convention on Biological Diversity and the technology has been widely condemned as a threat to food security for the 1.4 billion people who depend on farm-saved seed.<sup>224</sup>

The argument in support of using Terminator is that genetically engineering sterility would offer a built-in safety feature: if modified genes from a Terminator crop get transferred to related plants via cross-pollination, the seed produced would be sterile – the seed would not germinate and contamination would therefore not spread. However, the technology would need to be 100% effective to be considered as a potential bio-containment tool, and scientists who have studied genetic seed sterilization models argue that this guarantee is not possible.<sup>225</sup>

The technology also poses its own contamination risks. In the first generation, pollen from Terminator crops can move to other open-pollinated crops and wild relatives nearby. Farmers who find Terminator seeds in their harvest could lose the use of their traditional and local varieties and be forced to abandon their seed stocks adapted to local conditions and community needs.

# THE IMPORTANCE OF AGROBIODIVERSITY

**B**iodiversity is important not just outside farm fields, but also within them. Agricultural biodiversity, or agrobiodiversity, is the variability in our crops, livestock, fisheries and forestry. This includes diversity within species,<sup>226</sup> as well as between species. It refers to the number and types of varieties of plants and breeds of animals we grow and use as food, fodder, fibre and fuel. It also refers to the vast range of organisms that keep our soil healthy, and our crops pollinated, and the range of organisms in neighbouring ecosystems, such as forests, grasslands and aquatic systems, which interact with agro-ecosystems.<sup>227</sup>

Agrobiodiversity is important for a number of reasons. A large proportion of biodiversity around the world can be found in agricultural landscapes, and it supports other diversity off the farm. Plant and crop diversity, for example, is necessary for pollinator and bird diversity, which in turn supports species that may act as natural predators for pests and diseases.

Agrobiodiversity is also closely related to food security, and is key to our ability to adapt our agricultural systems to a changing climate. The greater the crop and genetic diversity within a population, the higher the chances that at least some varieties or individuals in that population will be able to tolerate stresses. This diversity also provides the genetic

pool that public breeders and farmers can use to develop new varieties. The erosion of agrobiodiversity destroys not only varieties that are important now, but also a vast range of potential future crops, and reduces our options for future agricultural adaptation.

Livestock and crop diversity has been – and continues to be – lost at an alarming rate. In the past century, we have lost over 75% of the world's crop diversity.<sup>229</sup> Seeds of Diversity Canada estimates that farmers and gardeners in Canada grew approximately 35,000 varieties of food plants just a few generations ago.<sup>230</sup> As in the rest of the world, three quarters of these varieties could now be extinct.

Climate change will further exacerbate this loss. As changing conditions and more extreme weather add more stress to agricultural systems, more species may be at risk of extinction. Scientists estimate that approximately 20-30% of all species are likely to be at risk of extinction if global average temperatures increase by 1.5-2°C.<sup>231</sup>

This alarming biodiversity loss is driven by a number of factors including habitat loss, population growth, climate change, environmental degradation and, importantly, the development of just a few crop varieties that have replaced a wider diversity of farm-saved, locally adapted varieties and landraces.

“ Biodiversity underpins to food security, sustainable livelihoods, ecosystem resilience, coping strategies for climate change, adequate nutritional requirements, insurance for the future and the management of biological processes needed for sustainable agricultural production.<sup>228</sup> — United Nations Food and Agriculture Organization, 2010

Industrial agriculture has encouraged shifts to growing a small number of varieties in large-scale monocultures. Large corporations focus on developing and selling these few varieties, which are bred for uniformity, and focus on characteristics such as storability, transportability and yield, often at the cost of other environmental adaptations. In addition, the shift to hybrid and proprietary seed varieties (including GM seeds under patent protection) has meant that many farmers buy seed every year, and do not save their own locally adapted seed. Small-scale diverse farming models are marginalized in such systems, and commercial varieties often replace diverse traditional varieties.<sup>234</sup>

GM seeds and crops are a product of this approach to agriculture, and have perpetuated the loss of agrobiodiversity. Like the wider agricultural approach they are rooted in, GM technology has encouraged the use of a handful of genetically uniform commodity crops, engineered with just a few traits.

## Agrobiodiversity over the past century<sup>232</sup>

75% of global plant genetic diversity has been lost.

30% of livestock breeds are at risk of extinction; six breeds are lost each month.

Today, 75% of the world's food comes from 12 plants and five animal species.

Just five crops – rice, maize, wheat, millet and sorghum – provide 60% of the world's food energy.<sup>233</sup>

## AGROBIODIVERSITY IN A CHANGING CLIMATE

The warming of the planet will lead to changes that are hard to predict with precision. Scientists are not sure, for example, whether temperature changes will mean that crop flowering times will change, and whether pollinators will be able to synchronize their behaviour fast enough to adapt to those changing patterns. They also suspect that some pathogens and pests will be able to evolve rapidly, potentially causing damage to agricultural ecosystems, and that invasive plants may crowd out species in forest ecosystems.

These changes are all going to increase the need for crops that have diverse and resilient genetics, and that are able to adapt rapidly to changing conditions. Major seed companies around the world have patented gene sequences to genetically engineer “climate-ready” crops that could respond to environmental stresses.<sup>235</sup> However, a number of studies have already found that traditional varieties perform better than modern ones in stressful or extreme conditions. Summarizing two studies, a UN FAO report on biodiversity and food says, “Under stress conditions, the risk of crop failures is lower with landraces than with modern varieties; for example, yield under stress of barley landraces was between 25 and 61% higher than non-landraces... Modern varietal mixtures of many crops can also out yield the mean of their monocultures: wheat mixtures, for instance, have proven to have a yield advantage of 19% over monocultures.”<sup>236</sup>

Every variety that we have lost, and continue to lose, lowers the genetic diversity in our crops, which in turn reduces our ability to adapt to climate change, diseases and other stresses. Some of the crop varieties that are now extinct may have been better adapted to specific environmental conditions and to the impacts of climate change. **GM crops perpetuate this degradation of agrobiodiversity, and are not a long-term or resilient approach to future agricultural adaptation.**



## FUTURE GMOS, FUTURE RISKS

In addition to examining the environmental impacts of the current applications of GM technology, it is necessary to look toward the potential risks of future applications. These include risks in Canada from the introduction of recently approved GM “non-browning” apple trees, the potential commercial production of GM fast-growing Atlantic salmon, and the pending introduction of herbicide-tolerant and low-lignin GM alfalfa. There are also other possible applications of genetic engineering on the horizon, in forest trees for example, that pose grave risks.

Each genetically engineered organism poses new potential risks, based on the GM trait(s), the contamination potential unique to the biology of that organism and how it is used in agriculture, and its ecological role.

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### GM ALFALFA

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The release of GM glyphosate-tolerant alfalfa has been delayed in Canada since 2013 because of farmer and consumer protest. The company Forage Genetics International already sells GM alfalfa with Monsanto’s GM glyphosate-tolerant Roundup Ready trait in the US, but has confirmed it will not sell the seed in Canada in 2015.<sup>237</sup> In late 2014, Monsanto was also granted approval in both Canada and the US to sell its GM low-lignin alfalfa.

If GM alfalfa is introduced, the flow of genes and traits from GM to non-GM alfalfa will be unavoidable. GM alfalfa would be the first genetically engineered perennial crop in Canada. Alfalfa’s biology and the ways in which it is used make it particularly prone to contamination.

Alfalfa is pollinated by insects. Alfalfa seed is very small and the likelihood that seed may spill during planting, transport and harvest is very high. Alfalfa also survives well as a feral plant in unmanaged habitats like ditches, and feral alfalfa will further exacerbate the unwanted spread of GM alfalfa plants.

Alfalfa is a very important crop in many farming systems in Canada, and is particularly important for organic and ecological farmers who use it to build soil fertility. Alfalfa is also high protein animal feed for livestock and GM alfalfa contamination in forage crops and pasture would pose a serious threat to organic farming, particularly organic dairy, but also grass-fed beef production. Organic and non-GM farmers would bear the costs of removing GM alfalfa plants from their farms with little prospect of compensation, and organic farmers would risk losing their organic certification.

In 2013, two Ontario farmers, supported by CBAN, the National Farmers Union-Ontario and the Organic Agriculture Protection Fund of the Saskatchewan Organic Directorate, requested an environmental assessment of Roundup Ready alfalfa under Ontario’s Environmental Bill of Rights. In addition to outlining the risks and consequences of contamination for Ontario farmers, the farmers argued that the introduction of Roundup Ready alfalfa would increase herbicide use in the province and threaten biodiversity.<sup>238</sup>

The introduction of Roundup Ready alfalfa would increase the use of glyphosate and accelerate the development of glyphosate-resistant weeds. In Canada, herbicide use in alfalfa is limited to spraying prior to seeding or after harvest to kill (burn down) the alfalfa before planting another crop. Alfalfa is most commonly grown without pesticides because it is grown in mixed stands with grass species that would also be killed by sprayings. However the release of Roundup Ready alfalfa would encourage a shift from diverse forage to pure alfalfa stands which would also reduce biodiversity.

Forages such as alfalfa are the only modern crop type that includes genetic diversity both within and among species in the same field at the same time.<sup>239</sup> Forage stands are often a mix of legumes and grasses that provide habitat for wildlife in Ontario, including threatened bird species, and support a number of pollinators and other insects.

These species are then preyed on by other wildlife, such as birds, hunting mammals, and snakes, making them the first link in a large food chain.

Perennial forages such as alfalfa provide a range of important environmental services.<sup>240</sup> Forage legumes are included in crop rotations to help build nitrogen levels in the soil, maintain soil fertility, prevent erosion, and increase soil aeration. Ploughing alfalfa into the soil builds organic matter, and increases the soil's ability to hold moisture and sequester carbon. Such environmental benefits would be lost if more alfalfa is grown in pure stands, or if fewer farmers grow alfalfa in order to avoid costs and liabilities relating to contamination from GM alfalfa. *For more information, see CBAN's 2013 report The Inevitability of Contamination from GM Alfalfa Release in Ontario.*

[www.cban.ca/alfalfa](http://www.cban.ca/alfalfa)

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## GM FISH

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In November 2013, Canada's Minister of the Environment approved the commercial production of the world's first genetically modified fish:<sup>241</sup> a GM salmon developed by the US company Aqua-Bounty. This GM fish has not yet been approved for human consumption in Canada, or anywhere else in the world, so it is not yet being grown at a commercial scale, however Canadian and/or US regulators could approve it for eating at any time.

The salmon are engineered with a growth hormone gene from Chinook salmon and genetic material from ocean pout (an eel-like creature), to grow faster. The company's initial plan is to produce the GM fish eggs in Prince Edward Island and ship them to Panama for grow-out and processing.<sup>242</sup>

The Canadian decision to allow GM salmon production is being challenged in court by Ecology Action Centre (Nova Scotia) and Living Oceans Society (British Columbia).<sup>243</sup> The groups argue that the government should have assessed the risks that the GM fish poses if it escapes, rather than just assess the strength of the company's containment plans. The escape of farmed fish from marine net pens and hatcheries is already a serious, recurring

problem. Because of this risk, the company Aqua-Bounty is relying on land-based containment. The company also says that all the fish will be sterile females,<sup>e</sup> but this sterility can only be guaranteed up to 95%.<sup>244</sup> Even if only 1% of the GM fish remain fertile, escape from confinement would pose a significant threat to the future of wild Atlantic salmon populations, many of which are endangered.

Research from the Department of Fisheries and Oceans with experimental GM Coho salmon found that GM salmon are more aggressive and could outcompete wild salmon for food.<sup>245</sup> GM Atlantic salmon may survive and breed in the wild, and is capable of breeding with brown trout.<sup>246</sup> The true environmental impacts will only be known when escape occurs.

[www.cban.ca/fish](http://www.cban.ca/fish)

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## GM APPLE TREES

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On March 20, 2015, Canadian regulators approved the first GM tree, and first GM fruit, for growing in Canada. The apple is genetically engineered so that the apple flesh does not brown after being cut, for 15-18 days.<sup>247</sup> These GM apple trees can now be legally planted in Canada (and the US), with apple blossoms flowering in Canada as early as 2016. Though it takes several years to establish an apple orchard, the company says that some GM apples could be on the market in late 2016.<sup>248</sup>

Apple trees are pollinated by bees. There are more than 450 bee species in BC<sup>249</sup> and many small orchards support a great variety of these wild and native bee species, which can travel long distances. The company, Okanagan Specialty Fruits, argues that the risk of cross-pollination is low because bees will stay close to their hives when there is enough food, such as when an orchard is in bloom, and that

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e Sterility in the GM fish is established through the process of triploidy where fish eggs are subjected to pressure or other treatments resulting in (most) fish carrying three instead of the normal two (diploid) sets of chromosomes. This takes away the ability to reproduce.

“dense orchard plantings and buffer rows make it very difficult for bees to maneuver far, so the risk of bees carrying pollen far enough to be an issue is almost nonexistent.”<sup>250</sup> But many orchardists disagree, especially when they consider the behaviour and diversity of native bees.<sup>251</sup>

Contamination through seeds is also a potential threat. Apple blossoms that are pollinated with pollen from GM trees will produce apples whose seeds could contain the new gene sequence. Although commercial producers do not usually grow apple trees from seed, GM apple seeds could germinate and grow into viable fruit trees. Seeds can spread through the environment from discarded apple cores, including when eaten and spread by animals.

[www.cban.ca/apple](http://www.cban.ca/apple)

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## GM FOREST TREES

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The release of GM trees has begun. In addition to the GM apple trees, in 2014 the US government approved a loblolly pine that is genetically engineered for altered wood composition (for biofuel production) (this approval only came to light in 2015)<sup>252</sup> and the Brazilian government approved the commercial growing of GM eucalyptus on April 9, 2015. The Canadian government has allowed field tests of GM trees beginning in 1997,<sup>253</sup> and has invested in ongoing GM tree research through the Canadian Forest Service of Natural Resources Canada.<sup>254</sup>

Experiments with GM trees have enormous potential for gene flow because trees are large, long-living organisms that produce abundant pollen and seed that are designed to travel long distances,<sup>255</sup> through wind dispersal as well as with help from animals.<sup>256</sup> There is a very high risk that GE trees will contaminate native forests, with unpredictable and complex impacts on forest ecosystems.

**Once such contamination begins, it cannot be stopped. GM trees will contaminate native forests, which themselves will become contaminants, in a never-ending cycle.**

Scientists at the Canadian Forest Service have already warned that, “gene flow from genetically modified trees will occur unless they are strictly made unable to reproduce.”<sup>257</sup> Suggestions about

the role of sterility technologies in relation to releasing GM trees are common because of the recognized contamination threat<sup>258</sup> but these technologies would not be reliable and pose their own environmental risks (see page 29 on Terminator technology). Despite the warning of inevitable contamination, Canadian government experimentation with GM trees continues.

GM trees threaten forest ecosystems. Forests include some of the world’s most important biodiversity reserves, with some forest soils alone containing thousands of species. Canada’s boreal forest is one of the largest and most ecologically significant ecosystems on the planet. It moderates the climate, produces oxygen, purifies the water that we drink, stores billions of tons of carbon, and is home to thousands of tree, plant, animal, bird and insect species.

The commercial introduction of GM trees could also have indirect impacts on the environment. Commercial and industrial scale biofuels production is already driving the conversion of forests and other natural ecosystems to the cultivation of crops and trees for fuel.<sup>259</sup> Historically, the use of tree monocultures throughout the world has resulted in the widespread simplification of ecosystems and extinctions of endemic species.<sup>260</sup> Genetically engineering trees in order to more efficiently manufacture them into biofuels and pulp and paper, for example, could increase the economic pressure to convert land into plantations.

CBAN, in community with groups across the world, has reached the conclusion that **“The only reliable method for preventing the escape of genetic material such as transgenes from genetically engineered trees is to not release such trees into the open environment.”**<sup>261</sup> In 2008, CBAN and groups across the world supported a call for a global ban on GM trees at the United Nations Convention on Biological Diversity (CBD).<sup>262</sup> The call was supported by African governments but opposed by Canada and others, with the outcome that the UN CBD made several recommendations to strengthen national regulation and reaffirmed “the need to take a precautionary approach when addressing the issue of genetically modified trees”.<sup>263</sup>

“ GE trees have the potential to wreak ecological havoc throughout the world’s native forests. GE trees could also impact wildlife as well as rural and indigenous communities that depend on intact forests for their food, shelter, water, livelihood and cultural practices. As a geneticist, I believe there are far too many unknown and unanswered questions to be growing genetically engineered plants – food crops or trees – in open fields. GE trees should not be released into the environment in commercial plantations and any outdoor test plots or existing plantations should be removed. — David Suzuki<sup>264</sup>

**Table 3: Canadian Government approved field trials of genetic research in trees**

TREE SPECIES	ORGANIZATION	YEAR	NUMBER OF TRIALS	RESEARCH FOCUS	LOCATION
Hybrid Poplars ( <i>Populus alba xgrandidentata</i> )	Unknown	1997	1	Genetic Research	Quebec
Hybrid Poplars ( <i>Populus alba xgrandidentata</i> )	Alberta Pacific Forest Industries	1998	1	Herbicide tolerance (glyphosate-resistance), genetic marker research	Alberta
Black Spruce ( <i>Picea mariana</i> )	Laurentian Forestry Centre (Canadian Forest Service-National Resources Canada)	2000-2004	2	Genetic Research	Quebec
White Spruce ( <i>Picea</i> )	Laurentian Forestry Centre (Canadian Forest Service-National Resources Canada)	2000-2006	1	Insect resistance	Quebec
Hybrid Poplars ( <i>Populus alba xgrandidentata</i> ) and Poplars ( <i>Populus spp.</i> )	Laurentian Forestry Centre (Canadian Forest Service-National Resources Canada)	2000-Present	Ranging from 1-11 per year	Genetic research, herbicide tolerance, modified carbohydrate content, modified secondary metabolites, fungal resistance, antibiotic research	Quebec
Poplars ( <i>Populus spp.</i> )	Queen's University	2009-Present	1	Genetic and antibiotic research	Ontario

# CONCLUSION

**T**he use of genetically modified herbicide-tolerant and insect-resistant crops in Canada over the past twenty years has driven up pesticide use and exacerbated the spread of weed and insect resistance, had negative impacts on biodiversity, put non-GM crops and plants at risk of GM contamination, and perpetuated the ongoing erosion of genetic diversity in our agricultural crops. Future GM crops will likely have similar impacts, and also pose new risks that are hard to predict.

These impacts are not just a product of GM technology, but also of the ways in which GM crops are grown. GM crops are rooted in, and reinforce, a model of agriculture that relies on fossil fuels, uses large amounts of energy, water, pesticides and fertilizers, and that produces large amounts of greenhouse gas emissions and waste. The monocultures that this system cultivates harm biodiversity, both on and off the farm. Many of these issues are connected to the reality that a small number of large companies increasingly control farm inputs including the seed system that is the foundation of all food and farming.

Canadian regulation is not set up to monitor and evaluate the environmental impacts of GM crops once they are released, or to learn lessons from impacts we have seen over the past twenty years.

In the absence of this evaluation, we are bound to simply recreate current environmental problems. New GM crops that have recently been approved, such as 2,4-D- and dicamba-tolerant crops that threaten to further increase herbicide use and the spread of herbicide-resistant weeds, clearly expose the dangers of this pattern.

Furthermore, our current regulatory system assesses individual GM crops for some of their environmental impacts, but does not evaluate their risks within the context of wider, complex ecosystems and agricultural use. Individual GM crops pose a number of the risks outlined in this report, but may also have longer-term, ecosystem level impacts that are hard to predict.

It is urgent, now more than ever, to reverse the patterns of industrial agriculture, and build resilient, diverse and sustainable agriculture and food systems. Organic and ecological approaches aim to reduce agriculture's reliance on chemical pesticides and fertilizers as well as reduce greenhouse gas emissions and resource use. These models are controlled by farmers, not corporations, are rooted in diverse and adaptable seed systems, and build biodiversity instead of eroding it.

## WHAT'S NEXT?

### THE PEOPLE'S FOOD POLICY

The People's Food Policy is the first ever Canadian food policy to be developed by individuals and organizations within the growing food movement. Over the course of two years, more than 3500 people participated in a grassroots process to collaboratively articulate a vision for a healthy, ecological and just food system that will provide enough healthy, acceptable, and accessible food for all. The Policy concludes:

*“The United Nations Special Rapporteur on the Right to Food has recently released a major report outlining how a wide-spread global shift to ecological agriculture would not only be environmentally superior to continuing an extensive reliance on chemical fertilizers, but that it would double food production in key areas of hunger in less than ten years, while strengthening resilience to respond to climate change. The People's Food Policy supports this call for a global shift to ecological agriculture. It is crucial that we move away from industrial linear systems that are reliant on purchased inputs and environmentally harmful practices and result in severe waste problems. Instead, food production must move toward more integrated circular ecological systems where “wastes” become nutrients.”<sup>265</sup>*

Specifically on GMOs, the People's Food Policy recommends:

- 1 Democratize science and technology policy and integrate the precautionary principle into all stages of decision-making.
- 2 Genetically-Modified Organisms (GMOs) are living pollution that self-replicate. They cannot be recalled or controlled once they have been released and can spread and interbreed with other organisms, thereby contaminating ecosystems and affecting future generations in unforeseeable and uncontrollable ways. Genetically Modified (GM) crops threaten agro-biodiversity which is fundamental to global food security, as well as threaten the future of organic food and farming through contamination. Existing GM crops should be phased out and there should be no further approvals of GM crops and animals. A just transition process, including financial and technical support, needs to be established to assist farmers to shift back to non-GM seed sources and to adopt ecological agriculture practices.
- 3 The power over seeds, and potentially breeds, represented by monopoly control has become a mechanism for transferring wealth from farmers and rural communities into the hands of corporations and their shareholders. Canada's patent legislation should be amended to explicitly disallow the patenting of life, including living organisms and genetic sequences.
- 4 Protect and support the open and free sharing of non-transgenic seeds and breeds as a fundamental practice of agriculture.
- 5 Establish a national ban on “terminator” technology and actively support the existing international ban at the United Nations Convention on Biological Diversity.

## JUMP OFF THE PESTICIDE TREADMILL

- The impacts of herbicide-tolerant crops on herbicide use in Canada need to be evaluated, along with the specific environmental and human health impacts of increased glyphosate use.
- The federal government should set herbicide-use reduction targets in all major field crops and include financial incentives or penalties in agricultural programs to support this policy. Such a program should support farmers to reduce herbicide use, without sacrificing profit.
- The federal government should halt the introduction of the already approved 2,4-D and dicamba-tolerant GM crops. The Canadian Food Inspection Agency should deregister 2,4-D and dicamba tolerant crops and halt any further approvals of herbicide-tolerant crops.

## STOP GM CONTAMINATION

- The federal government should stop all field tests of GM trees and place a moratorium on the approval of any GM trees in Canada.
- A national ban on the field testing and commercial release of “Terminator technology” in Canada would support the UN moratorium and follow the examples set by Brazil and India.
- Canada should ratify the UN Cartagena Protocol on Biosafety.

## RESEARCH AND DEBATE

In the absence of federal government action, there is a role for provincial governments. For example, in 1999/2000, the Environmental Commissioner of Ontario commented that, on the issue of GMOs, there were “important environmental issues to be considered. Currently those issues are not part of any public debate in Ontario, perhaps due in part to the limited information on ecosystem impacts”<sup>266</sup> and recommended:

- An independent provincial advocate for ecosystem protection capable of addressing GMO issues.
- Government funded independent research and thinking on some of the fundamental ecological questions related to genetically modified organisms.

## MORE RESOURCES

### GLYPHOSATE

- Herbicide tolerance and GM crops: Why the world should be Ready to Round up glyphosate. GM Freeze and Greenpeace. June 2011.
- Roundup and birth defects: Is the public being kept in the dark? Antoniou et al. Earth Open Source. June 2011.
- National Farmers Union of Canada, Glyphosate: Frequently Asked Questions – A National Farmers Union Factsheet, National Farmers Union Newsletter. April 2015 <http://www.nfu.ca/story/union-farmer-newsletter-april-2015>

### GM ALFALFA

- The Inevitability of Contamination from GM Alfalfa Release in Ontario: The case for preventing the introduction of Roundup Ready Alfalfa. Canadian Biotechnology Action Network. April 2013. <http://www.cban.ca/alfalfaONreport>
- Application for Review: Under Part IV, Environmental Bill of Rights, Ontario. Request for Environmental Assessment of Genetically Engineered Roundup Ready Alfalfa. Submitted to the Environmental Commissioner of Ontario. July 2013. <http://www.cban.ca/content/view/full/1776>

### GM TREES

- Genetically Engineered Trees: The New Frontier of Biotechnology. Center for Food Safety. November 2013.

### GENERAL

- GMO Myths and Truths, EarthOpenSource, Second edition. May 2014 <http://earthopensource.org/earth-open-source-reports/gmo-myths-and-truths-2nd>
- Resetting the Table: A People’s Food Policy for Canada. April 2011. <http://foodsecurecanada.org/resettingthetable>
- SeedMap. USC Canada. [www.seedmap.org](http://www.seedmap.org)

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